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VOL. 2 NO. 1 MARCH 1915

PROCEEDINGS 35TH YEAR

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

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AMERICAN WATER WORKS ASSOCIATION

AT 2419-21 GREENMOUNT AVE., BALTIMORE, MD.

SECRETARY'S OFFICE, 47 STATE ST., TROY, N. Y.

Entered as second class matter April 10, 1914 at the Post Office at Baltimore, Md., under the act of August 24, 1912

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VOL. 2 MARCH 1915 No. 1

THE YONKERS WATER SUPPLY AND ITS FUTURE DEVELOPMENT

By D. F. Fulton*

The city of Yonkers, the sixth city in respect to population, of the state of New York, adjoins New York City on its northerly line. It extends from the Hudson River, on which it has a frontage of about four and one-half miles, easterly to the Bronx River and occupies the southwesterly corner of Westchester County. In common with the remaining portion of the southerly part of the county it felt, during 1910 and 1911, the pinch of poverty, as regards water supply, a condition made acute by the unusual dryness of those years together with the ever increasing demands on the supply due to a rapid growth in population and to the increase in consumption by new or expanding manufacturing industries.

The rainfall records of the Water Bureau, continuous since 1878, with the observing station less than one-half mile from the storage reservoir indicates the rainfall of 1910 to be eighteen inches below the average for thirty-three years and that of 1911 to be eleven inches below the average for thirty-four years.

For some time past, it has been plain to the city authorities that the present supply would soon be insufficient to meet requirements and various measures have been adopted to conserve and augment the supply and to minimize waste. These measures although fairly

*City Engineer, Yonkers, N. Y.

successful were not, nor were they expected to be sufficient to relieve the situation for any length of time and Yonkers now proposes to obtain water to meet estimated demands for a period of from fifteen to twenty years.

Before describing the method by which it is proposed to obtain this increase, a brief historical outline of the origin and growth of the present supply and works will perhaps be interesting.

Topographically, Yonkers is divided into a series of ridges and valleys extending in a generally north and south direction. The northerly part of the city is traversed by three streams, the largest and most westerly of which is the Saw Mill or Nepperhan River which in former years was the source of power for many mills in Yonkers and which when it reaches the center of the city flows westerly into the Hudson River.

Occupying the next valley to the east of the Saw Mill River and separated from it by a high narrow ridge, is the Sprain. East of the Sprain and similarly separated from it, lies the Grassy Sprain. Within the city, however, they meet and flow in a southeasterly direction into the Bronx River.

In 1876 there was constructed what has generally been known as our Grassy Sprain Supply.

A canal, part of the original works, diverts the flowage of the upper Sprain into the Grassy Sprain and this combined catchment area amounts to 4½ square miles.

On the Grassy Sprain a storage reservoir was formed by the construction of an earth dam with flowline at about elevation 118, the capacity of which was 440 million gallons. Water was pumped to the small Lake Avenue Reservoir and from it flowed by gravity into the distributing mains.

About 1885, a tank or tower was constructed near the Lake Avenue reservoir, a pump installed, and the water repumped to the tower. This arrangement with an additional tower and some enlargements constitutes our high service system today.

By 1895, the draught had become so heavy that the supply was somewhat augmented by driving, in the Saw Mill River Valley, some 12 to 15 tubular wells. These wells averaged about 40 feet in depth, tapping the underground water stored in the sandfilled valley. A pumping plant was installed at the site of these wells and the water pumped directly into mains. This station has come to be known as our tubewell or Nepperhan Pumping Station.

At this time Fortfield Distributing Reservoir with flowline at approximately the same elevation as the Lake Avenue Reservoir but with a capacity of 60 million gallons, was constructed.

For some time additional water, amounting to about a million gallons daily, was thus obtained, but the level of the ground water was in the meantime lowered about 28 feet so that by 1903 the amount thus secured had become somewhat less.

In 1903, the supply was further increased by the construction, at the site of the Tube Wells Pumping Station, of two filters of one-half acre each. These filters were of the open, slow sand type and were designed to help out during the summer months.

The filters took the raw water of the Saw Mill River, and for ordinary stages of the river, and in open weather answered their purpose well. They had a combined rated capacity of 3 million gallons daily.

Prior to 1905 and during the spring freshets, considerable water went over the spillway of the Grassy Sprain Dam. In order to avail ourselves of this water the dam was raised about 12 feet, which added height increased the capacity from 440 to 960 million gallons. In 1909 two additional filters of three-quarters of an acre each, of the covered slow sand type and with a combined rated capacity of 4.5 million gallons, were completed.

To permit of the temporary cutting out of a bed, for repairs or cleaning, and in order to secure additional capacity two more filters of the same type and size as those last constructed have just been added to the plant. This brings the total to 4 acres of filters with rated capacity of 12 million gallons daily on the basis of 3 million gallons per acre per day.

In the summer months, when the draught on the supply is heavy, we have an ample capacity in the filtration plant, but unfortunately not sufficient water in the stream.

It is not possible, within reasonable limits of cost, to provide storage at the site of the filters, and as a consequence raw water has to be admitted directly to them. In times of flood, when there is an abundance of water in the Saw Mill River, it unfortunately carries a large amount of matter in suspension. At such times they have to be closed down, and considerable water passes by unused.

These were the conditions with which we faced the unusually dry years of 1910 and 1911.

While Yonkers has been particularly fortunate during the past

four years, the situation at that time was one that required immediate relief. It also emphasized the necessity of developing a plan that would embrace storage sufficient to carry us over at least one dry year, and at the same time to provide a supply ample to meet requirements for a term of years.

In December, 1910, a Joint Water Supply Committee consisting of councilmen and citizens was appointed by the mayor. The committee, after resolving itself into a working body, retained as consulting engineers, to examine into and report on an increased water supply, Messrs. Hazen and Whipple.

As a temporary alleviation of the conditions then existing it was recommended by them, that, inasmuch as all the water reaching the filters was not being used, the rate of filtration be increased to such an extent that practically the entire draught, when possible, should be taken from them.

With the use of hypochlorite in conjunction with the filters it was recommended that the old rate of 3 million gallons per acre, daily, could be safely increased at least 50 per cent, and when this practice became effective the Grassy Sprain Reservoir, being relieved of the draught, began to fill and immediate danger was averted.

In November, 1911, the consulting engineers submitted their report which in substance covered the recommendation that an increased supply of water for the city of Yonkers was to be most economically obtained by developing up to about ultimate capacity, our present sources.

From what has heretofore been said it will be remembered that Yonkers is now obtaining water from three separate sources.

(1) The Grassy Sprain Supply.

(2) The Saw Mill River or Filtered Supply.

(3) The Tube Well Supply.

The amount of water, however, obtained from this last source is very small, almost neglible, so that for all practical purposes our present supply will be considered as from Grassy Sprain and Saw Mill River.

The Grassy Sprain supply, with the raising of the dam in 1905, increasing the storage from 440 to 960 million gallons, saw that supply developed to about its ultimate capacity.

It must be inferred, then, that the development to which reference has heretofore been made means the development of the Saw Mill River supply and in fact that is the substance of the report.

THE REPORT

As an index to the size of works probably required, the population and consumption of the city for the years 1915 to 1930 has been estimated and together with population and consumption for the years 1880 to 1910 is shown in the following table.

Year	*Population*	*Million gallons per day*	*Gallons per capita*
1880	18,892	0.86	46
1890	32,033	2.17	68
1900	47,931	3.25	68
1910	79,803	8.20	103
	Estimated		
1915	101,000	10.2	100
1920	129,000	12.9	100
1925	160,000	16.0	100
1930	197,000	19.7	100
1935	240,000	24.0	100

To many only slightly familiar with conditions in Westchester County it might appear that a supply sufficient to meet the requirement for the year—say—1930 could readily be obtained in the northern part of the county.

A study of the map herewith shown, however, will indicate pretty clearly that New York City has been first on the ground, and when a search is made for a supply of this size it is not quite such a simple problem as at first blush might appear.

In the investigation looking to an outside supply a canvass was made for a considerable distance north of Yonkers of all available catchment areas. Those of Sprout Brook, Oscowanna Brook and Peekskill Creek were considered as affording the most economical sources from which a considerable supply of water could be obtained.

By the construction of dams on Sprout Brook and Peekskill Creek, it was set forth that a supply of 40 million gallons per day could be delivered by gravity at an approximate cost of $9,500,000 or at a cost of $234,000 per million gallons daily.

Inasmuch as Peekskill has the first right to the water of Peekskill Creek and Oscowanna Brook, and because of the large amount of capital required for the development, this source was not favorably accepted by the committee.

However, should the future make it desirable for a Metropolitan District for lower Westchester County, this would afford an admirable supply sufficient for a population of 400,000 people.

In general the plans submitted by Hazen and Whipple and adopted by the Joint Water Supply Committee provides for obtaining an increased supply of water from the Saw Mill River. This is to be accomplished by:

(1) Control of flood flows of that river, by enlarging the present Grassy Sprain Storage Reservoir, and the construction of two additional reservoirs.

(2) By the filtration of all water used by the city of Yonkers.

CONTROL OF FLOOD FLOWS OF SAW MILL RIVER

Reference is again called to the map on which is shown a proposed reservoir at East View. Behind this site is a catchment area of about 12 square miles. It is proposed to build here an earth dam, 20 feet wide on top, maximum height 47 feet, 400 feet long at the flowline and provided with gate house and overflow.

With the flowline of this reservoir at elevation 230 and with a capacity of 560 million gallons it is proposed to arrest the floods of the upper area and by the operation of regulating gates this stored water will be passed down the stream to Woodlands Lake, an existing artificial lake with spillway at elevation 155, where an intake is to be constructed.

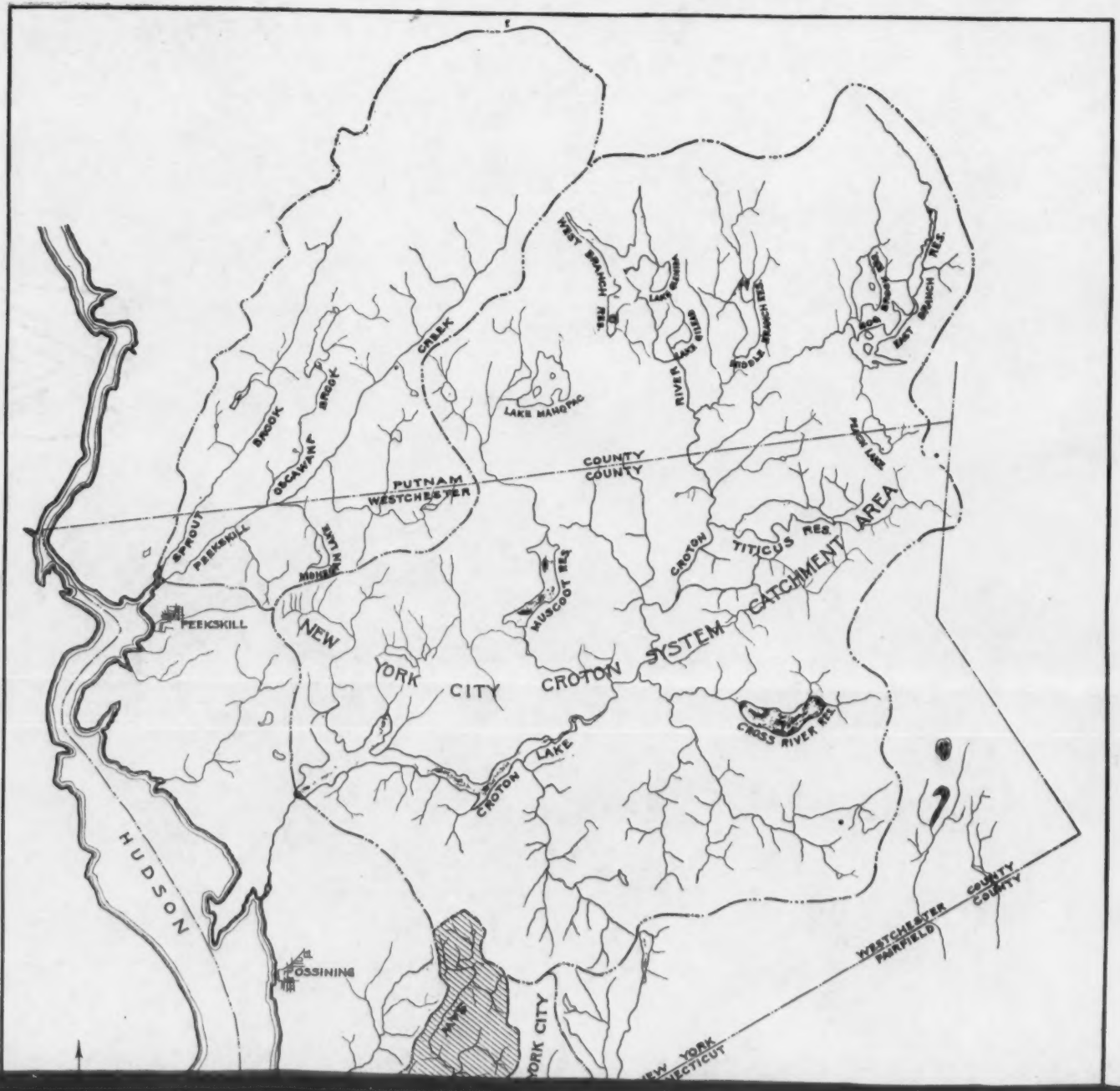
From Woodlands Lake a 72-inch aqueduct and tunnel will conduct the flowage through the ridge into the upper Sprain.

It is to be here noted, that the water of the Saw Mill River, a tributary of the Hudson, is to be diverted to the Sprain, a tributary of the Bronx.

In the lower Sprain Valley it is proposed to form a reservoir by constructing an earth dam 50 feet high and 350 feet long. The reservoir will have a flowline at elevation 147 with the top of the dam at elevation 155.

The Sprain Reservoir, it will be noted from the map, lies directly west of the Grassy Sprain Reservoir, which is to be enlarged by the construction of an earth dam 40 feet higher than the present one, and about 350 feet down stream from it. It will be about 24 feet wide on top and 1070 feet long.

Underlying the present dam, preliminary borings indicate rock at a depth of 90 feet below the brook. The Rock Valley is wide so that there is a large section of material overlying it. This material is largely sand of varying degrees of coarseness, much of it is so coarse as to carry water freely.


PUTNAM COUNTY
WESTCHESTER COUNTY
LAKE MAHOPAC
WEST BRANCH RES.
MIDDLE BRANCH RES.
EAST BRANCH RES.
CROTON
TITICUS RES.
CATCHMENT AREA
MUSCOOT RES.
NEW YORK CITY CROTON SYSTEM
CROSS RIVER RES.
CROTON LAKE
PEEKSKILL
SPROUT BROOK
PEEKSKILL HOLLOW BROOK
MOHEGAN LAKE
OSCAWANA BROOK
HUDSON
OSSINING
NEW YORK CITY
WESTCHESTER COUNTY
FAIRFIELD COUNTY
NEW YORK
CONNECTICUT

CROSS RIVER RES.
CROTON LAKE
HUDSON RIVER
OSSINING
WESTCHESTER COUNTY
FAIRFIELD COUNTY
NEW YORK
CONNECTICUT
NEW YORK CITY
MILL
TOMAHAWK
EAST VIEW RES. (Proposed)
KENSICO RES.
ASTOR POND
TARRYTOWN
SAW MILL RIVER
BRONX
WOODLANDS LAKE
WHITE PLAINS
HASTINGS
GREENBURGH
RIVER
SPRAIN RESERVOIR (Proposed)
GRASSY SPRAIN RES.
FILTER BEDS
WATER CO.
MAMARONECK
SOUND

FILTER BEDS
YONKERS
NEW ROCHELLE WATER
NEW YORK CITY
LONG ISLAND
CATCHMENT AREA OF PROPOSED SOURCES — SHOWN THUS
MAP SHOWING
PROPOSED DEVELOPMENT OF
WATER SUPPLY
YONKERS, N.Y.

For the new dam, it is proposed to provide a cut-off for this underground flowage. It has been suggested that this can be done either by driving steel sheet piling to rock or in the deeper part of the valley by sinking a connected series of caissons and filling them with grout or concrete.

A 6-foot tunnel is to be driven through the ridge between the two reservoirs which will permit filling the Grassy Sprain Reservoir up to elevation 147 by gravity.

The flowline of the enlarged Grassy Sprain Reservoir will be at elevation 170 and to fill the upper 23 feet it is proposed to install a pump at the entrance of the tunnel to be operated by an electric motor, the current for which will be furnished by a generator at the Filter Bed Pumping Station.

Water will be drawn by gravity from either or both of these reservoirs through 48-inch lines to the filter beds. Under ordinary operations the water will be drawn from the Grassy Sprain Reservoir.

It will be noted that by this arrangement no raw water will be taken to the filters but water, only after a considerable period of settling, storage and bleaching both in the Sprain and Grassy Sprain Reservoirs, will be admitted to them.

The filtered water will be pumped directly into the mains and also to the Fortfield Reservoir. This is an open reservoir with a capacity of about 60 million gallons, divided into two equal parts by a masonry wall. It is part of the general scheme to raise and cover this reservoir. Raising has been suggested because it can be done with but little additional cost in connection with the covering.

With the completion of the above outlined works, with a total catchment area of about 24 square miles, it is somewhat conservatively estimated that a supply of about 18 million gallons per day in an ordinary dry year will be obtained. In other years it is expected that from 20 to 22 million gallons daily will be obtained.

With all reservoirs filled we will have 5700 million gallons of water in storage, an amount sufficient for a year's supply at 18 million gallons per day.

This storage will be distributed as follows:

	Gallons
East View Reservoir	560,000,000
Sprain Reservoir	380,000,000
Grassy Sprain Reservoir	4,700,000,000
Fortfield	60,000,000
Total	5,700,000,000

The estimated cost of the works by which it is proposed to obtain an additional 10 million gallons per day is $3,073,000 which includes $1,000,000 for land.

This is at the rate of $307,000 per million gallons daily, a figure somewhat high, but which is made so, at least in part, by the estimated cost of land to be acquired. Also included in this cost, however difficult to determine, is the value both from a sanitary and commercial view point, of filtering only stored and settled water, as compared with the filtering of raw water, the method in use today.

DISCUSSION

MR. EDWARD L. PEENE: You have heard the paper, as well prepared as could be, on the question of our future water supply, and there seems to be nothing further to add. The speaker simply takes care of the maintenance of our water system, and he has all he can do to take care of that. You will notice that this increased supply is to be furnished at an estimated amount of 18,000,000 gallons per day. The present consumption is about 10,000,000 gallons per day. The population is about 100,000, and this is quite a small amount for such a large city. You know that Yonkers is about 100 per cent metered, and that is why we are able to keep down the amount of water used in the city. Our per capita last year ran close to 98, but, deducting the manufacturing, brings the domestic consumption to 29 gallons per day. Our average use per day for this year, to date, is 7,500,000 gallons, which is due to a completely metered system, and all water pumped being measured by a Venturi meter in place of plunger displacement as heretofore.

MR. ALLEN HAZEN: That is an interesting statement on meters. Can you tell us what per cent of the output is accounted for by your meters?

MR. EDWARD L. PEENE: About 60 to 65 per cent.

MR. JOHN C. TRAUTWINE, JR.: To one who, like the speaker, hails from one of New York's southern suburbs, where the percentage of taps metered approximates zero as a limit, and where the daily per capita draft is something like 180 gallons, or from two

to four times what it has any excuse for being, it is refreshing (if also humiliating) to learn, from Mr. Peene's discussion, that, in the northern suburb of Yonkers, where the percentage of taps metered is 100, the domestic draft is only 29 gallons per capita per day, less than 16 per cent of Philadelphia's, and yet ample; and that the city has been able to get along with a water supply which, under Philadelphia conditions, would have been ridiculously inadequate.

Only today, in this room, a fellow suburbanite, who lives in the fourth story of the Philadelphia Engineers Club, said that, in spite of a pumpage of say 180 gallons per capita per day, he could be sure of getting water from the tap on that floor only when, as happened this morning, he was forced to rise with or before the lark.

For a generation and more those in charge of Philadelphia's water supply have struggled for the introduction of meters, recognizing this as the key, the sufficient key, and the only key, to all our water troubles; and our City Charter expressly places the "Water Works . . . under the direction, control, and administration of the department of public works," expressly forbidding the City Councils to direct or interfere with the exercise of the Department's executive functions, and expressly commanding the City Councils to provide for the proper conduct of the works by the Department.

But, unfortunately, these provisions of the City Charter are a dead letter. The Councils usurp the executive functions of the Department; and, the water meter being practically unknown, and therefore unpopular, in Philadelphia, our city remains in the ranks of the back numbers. It is needless to say that she pays dearly for her backwardness.

Like its predecessors, the present reform administration, in its early days, vigorously espoused the restriction of waste by means of water meters. For the enlightenment of our unhappy people, it set up and maintained, in the City Hall courtyard, an exposition with a screen for lantern slides.

In his report for 1912 Director Cooke said:

> We are undoubtedly fortunate in lying at the junction of two such magnificent waterways as the Delaware and Schuylkill . . . but it is not wise to allow this good fortune to be given as an excuse for a profligate waste of water, a waste certainly amounting to one-half of all we use.
>
> (The Director doubtless means one-half of all we consume.)

In his report for 1911 Director Cooke said:

> From a study of the results obtained from other cities . . . there is hardly a doubt that, if meters were placed on those properties wherein waste is detected, the consumption would be so reduced that a good supply could be maintained in all sections of the city.

In short, the Department was aware that the use of meters would render the present supply absurdly ample for all the city's needs, for years to come. It is therefore, to put it mildly, disquieting to find the Department now nearly silent on the subject of waste restriction, and to hear Director Cooke publicly quoted as saying that the present supply must speedily be augmented, as favoring the bringing of additional water from distant sources, and as having asked the City Councils for an appropriation of $15,000 for the employment of experts to advise him in this connection. It is difficult to understand this abrupt and unfortunate change of base; but it may be well to remember the method adopted in the attempted introduction of meters.

Instead of installing meters at the city's discretion, and at the city's expense, the department merely made their use permissive, the consumer paying for the meter, hoping thereby to reduce his water bills. Under this arrangement, of course, meters were installed only, or chiefly, by "those just persons who needed no repentance," persons who wasted little or no water. The result of course was that the city revenue was reduced, without corresponding diminution of waste, and the meter system was brought into undeserved disrepute, to the joy of those who seek to profit by the city's historic plight.

Another fellow suburbanite recently pointed to the present European War as evidence of the alleged fact that the world has too much government, whereas, what the world needs for the prevention of such world nuisances, is a strong world-government, both ready and able to squelch promptly any upstart nation which might elect to derange the world-organization by playing soldier on its own account; and in Philadelphia we need a government which, taking its stand upon the City Charter, will meter the water supply, without a "by your leave" to our ignorant hoi polloi or to its representatives in the municipal legislature.

Mr. Fulton mentioned that, when the city of Yonkers set about utilizing a certain source of water supply in its vicinity, it found that the city of New York had already preëmpted that supply. Now it is not for us suburbanites to instruct the Metropolis in the

conduct of its affairs, but this statement of Mr. Fulton's indicates the need, in New York State, of some super-municipal administration of water supplies, on the lines of that created by our ever progressive brethren of Massachusetts.

Think of the absurdity of permitting New York City to provide itself with a water supply from within the state, not only without providing for the distribution of that supply among the cities and towns along the line of its conduit, but actually helping itself to a supply which it now appears belongs naturally and properly to one of those towns! What is the state for, if not to prevent such outrages?

As municipal water supply superseded the old-time individual water supply, under which each consumer drew partly from his neighbor's supply, and, incidentally, also from his neighbor's cesspool; so, the speaker ventures to predict, municipal water supply, a game of "Catch-who-catch-can," will be generally superseded, first by interurban water supply, as in the case of Boston and its surrounding communities, then by the state and interstate administrations, and, eventually and logically, by national, and finally by international water supply administration.

MR. ALLEN HAZEN: Mr. Trautwine's remarks on the Massachusetts control of waters are very interesting. Mr. Cuddeback and some others have been having experiences like that lately, and find that this makes it difficult for cities and towns to get water, which would be easily available if it were not for the state supervision as now conducted.

MR. JOHN C. TRAUTWINE, JR.: Mr. Hazen's statement that state control of waters in Massachusetts sometimes "makes it difficult for cities and towns to get water, which would be easily available if it were not for the state supervision as now conducted," is not at all surprising. It is even probable that the projectors of the New York City supply thought it best for the public welfare that there was no New York State authority to interfere with their designs upon Yonkers and her little ewe lamb.

Doubtless, after the Revolutionary War, when the original thirteen states had formed their "more perfect union," individual states now and then found that, in certain cases, the new Union made it difficult for them to get things which would have been easily

available if it had not been for the Union as then conducted; but probably everyone now recognizes that the benefits accruing to each of our states, by virtue of its present membership in the Union, vastly outweigh any possible inconvenience or loss of prestige or "identity" which that membership may entail.

Under the present "economic" system, which puts its premium upon self-seeking, it is only to be expected that each new adventure in further socialization will fail to work quite smoothly at first; but, in the long run, we do not generally find that, where such adventures have been made and carried out in the proper spirit, there has been general clamor for a reversion to the ancient rule of "every town for itself, and the devil take the hindmost."

OBSERVATIONS OF SOME EUROPEAN WATER PURIFICATION AND SEWAGE DISPOSAL PLANTS*

By Edward Bartow

During a trip to Europe in the summer of 1914, some of the European practices in water purification, in sewage disposal, and in laboratory control were observed. No special outline was made for the trip, beyond a plan to visit certain prominent men who would know the latest developments along the lines to be investigated. No definite schedule was planned, so that places off of a regular line might be visited, in accordance with the instructions of the men consulted. After August first, owing to the war, nearly three weeks of a gradually developed schedule had to be abandoned. It was impossible to carry out plans to visit Strasburg to see the fish ponds used for sewage disposal; Lunéville to see the water purification by means of ultra-violet rays; Frankfort, Cologne, the Essen district and Ghent, to see special methods of sewage disposal. No attempt was made to see any plants in the neighborhood of Paris. In London all permits to visit the reservoirs of the water department had been withdrawn, and armed guards watched the reservoirs day and night.

Many of the European water purification plants and sewage disposal works have been described by others, an attempt will be made, therefore, to describe only what seemed to be unique. Owing to the fact that water purification and sewage disposal are so closely related, a chronological order will be followed in the observations.

Hamburg was the first city visited. The water supply of Hamburg is taken partly from the Elbe River and partly from wells. The water works are located on the river above the city, but, the Elbe being a tidal water, at times the sewage polluted waters of the river reach the intake. It is customary only during the ebb tide to pump the water into the large settling basins. Altona which adjoins Hamburg down the river, obtains its water supply

* Paper read before a special meeting of the Illinois Water Supply Association (Illinois Section of the American Water Works Association), November 11, 1914.

from a point below the sewers of both cities. Reversing the practice of Hamburg, Altona pumps water into its purification works only during the flood tide. The Elbe River through Hamburg and Altona is therefore like a large tank disposing of the sewage which is passed into it. The only treatment Hamburg sewage receives is screening through revolving screens composed of aluminum bars about one foot long, placed about one centimeter (a little less than one-half inch) apart. The flow of the water in the river averages 1200 cubic meters per second. The dry weather flow of the sewage is 3 to 4 cubic meters per second, and the wet weather flow 20 cubic meters per second, so that there is ample dilution to prevent any nuisance, and to allow the water to be satisfactorily purified for drinking purposes. At the water purification plant alum is used as a coagulant prior to sedimentation. It is thought that Hamburg has the only purification plant on the continent where a coagulant is allowed. The water, after passing through large sedimentation basins, is filtered through slow sand filters (Fig. 1). These filters are uncovered, and in winter are covered with ice. Owing to the fact that there is a prejudice against the use of water taken from the river, the water department is endeavoring to develop a ground water supply. A number of wells have been sunk, and considerable water obtained, but the Hamburg authorities are handicapped by the fact that there is not sufficient area in Hamburg for proper development of ground waters. Hamburg is unable to extend its well system into Prussia, and, for the disposal of its sewage, has purchased from Prussia an island in the lower Elbe. The situation is similar to one in this country, where New York City cannot go outside of New York State to Connecticut or New Jersey for its water supply. The ground water obtained by Hamburg contains so much iron that iron removal plants have been constructed.

While the sewage from the city of Hamburg itself is easily disposed of by the dilution method, several of the smaller cities under the direction of the Hamburg authorities are located so far from the river that another means of purification is necessary. At Bergedorf, a city of 15,000 inhabitants, located about ten miles from Hamburg, no water whatever is available for sewage dilution. Purification is accomplished by Imhoff tanks and sprinkling filters, followed by fish ponds.[1] This is a modification of a system of

[1] K. Allen, *Municipal Engineering*, 47, 197–201.

purification introduced at Strasburg, under the direction of Professor Hofer of Munich,[2] where satisfactory results with a dilution of two or three parts of pure water are claimed. At Bergedorf with no dilution it has been possible to satisfactorily purify the effluent from the sprinkling filters. The purification is accomplished with the assistance of water plants (Fig. 2) which apparently remove the toxic properties of the sewage, and make the water suitable for fish culture. Fish placed in the ponds in the spring grow rapidly

FIG. 1. SLOW SAND FILTERS, HAMBURG, GERMANY

during the summer. The flesh is good, especially if the fish are transferred to pure water for one or two weeks before they are eaten.

At Berlin the Laboratory for Water Hygiene, located at Berlin-Dahlem, was especially interesting. In 1901 the Royal Research and Testing Station for Water and Sewage Purification was established. At the end of twelve years the organization had grown so

[2] Hofer, *Fischerei Zeitung*, 16, 148.

much that a new building costing $125,000 was constructed (Fig. 3). The name of the organization has been changed to "Landesanstalt für Wasserhygiene."[3]

This laboratory has control of the water supplies and sewage disposal plants in the province of Prussia. It also does commercial work for other German provinces and for foreign countries. Work of investigation is often done in coöperation with officers in cities and villages, and joint articles are frequently published by members of the staff and the city officials. At the present time the staff

FIG. 2. FISH POND AND LABORATORY OF THE BERGEDORF, GERMANY, SEWAGE DISPOSAL WORKS. PHOTOGRAPH BY DR. KEIM

numbers forty workers. The scientific publications from the laboratory are of great value. The new building contains library space which will accommodate 30,000 volumes. In July, 1914, one hundred and one journals were regularly received. An attempt was being made to have available for the use of the laboratory staff all literature in all languages, concerning water. In April and October instruction is given to water works men in methods of water supply and sewage disposal. Regular lectures are given, and the men are

[3] Mitteilungen aus der Königlichen Landesanstalt für Wasserhygiene, 17.

taken on trips to interesting plants in the neighborhood of Berlin. Professor Dr. Thum of the laboratory very kindly outlined several trips which would be most advantageous to take in the limited time which could be devoted to this section.

The water supply of Berlin is obtained partly from lakes and partly from wells. In Berlin, as in Hamburg, there is a prejudice against water from surface sources, and the authorities are endeavoring to replace the lake supplies by ground water supplies. At Mugglesee about one-third of the slow sand filters originally used to filter lake

FIG. 3. LABORATORY FOR WATER HYGIENE, BERLIN-DAHLEM, GERMANY

water have been given over to the removal of iron from ground water supplies obtained from wells near the lake. The water is pumped from the wells to elevated distributors, from which it trickles over many series of wooden gratings, during which process the iron becomes completely oxidized.

A new plant at Wuhlheide obtains ground water from eighty driven wells. It had been in operation only five days at the time of this visit. The water from the wells is pumped to the upper part of a high building (Fig. 4) and sprayed through special nozzles over beds of coarse gravel. The water having been thoroughly aerated and the iron oxidized, it is passed through pressure filters

(Fig. 5). The plant had been in operation only a few days, but, from the experiments from which the plant was designed, it is expected that good results in iron removal will be obtained.

The Prussian authorities are very particular to protect the streams from pollution by sewage. This is especially necessary because of the small flow and the sluggish character of the streams. Berlin proper owns large irrigation fields to which the sewage is pumped; 43,000 acres in all are owned; 21,000 are in use. It is rumored that

FIG. 4. IRON REMOVAL PLANT OF BERLIN WATER WORKS, WÜHLHEIDE

Berlin is giving up sewage irrigation. Berlin proper is not doing so. The suburbs have, however, found it necessary to adopt biological processes of purification because of the lack of suitable land for irrigation fields. The sewage from twelve districts in Berlin is pumped to various sewage fields. The fields at Gross Beeren are the largest in extent, and are typical of all the fields. The sewage passes through a pressure pipe line. An indicator tower shows the rate of flow. The heavy material is removed by open tanks. From the tanks it flows by gravity through open channels to the fields.

The land in the fields is rented to the peasants, who are willing to pay twice as much for lands inside these irrigation fields as for land outside. On some of the fields several crops are harvested each year. The vegetables raised were especially noteworthy, most of the vegetables used in Berlin being obtained from the sewage farms. One other crop is especially noteworthy, Italian rye grass, which may be harvested six times during the season. It grows to the height of a meter a month.

FIG. 5. PRESSURE FILTERS, IRON REMOVAL PLANT, BERLIN WATER WORKS, WÜHLHEIDE

Tanks or sprinkling filters are in use at Wilmersdorf, one of the larger suburbs, and in other parts of Greater Berlin.

Especial attention was called to the Reinsch screens[4] in use at Eberswalde. These are revolving screens having numerous holes about $\frac{1}{16}$ inch by $\frac{1}{2}$ inch. The screens are cleaned by revolving brushes. The sludge obtained is sold to the farmers who allow it to ripen for use as a fertilizer. Very complete purification is ob-

[4] *Engineering and Contracting*, 42, 273–6.

tained at Eberswalde. The sewage, after screening, is passed into septic tanks and through sprinkling filters with a unique system of distribution (Fig. 6). The sewage passes to a trough along the side of the filter beds. From this trough it is syphoned to a travelling cylindrical distributor containing numerous buckets. When these buckets are filled the weight causes the traveler to move. A check at the end of the bed reverses the flow and the direction of the traveler.

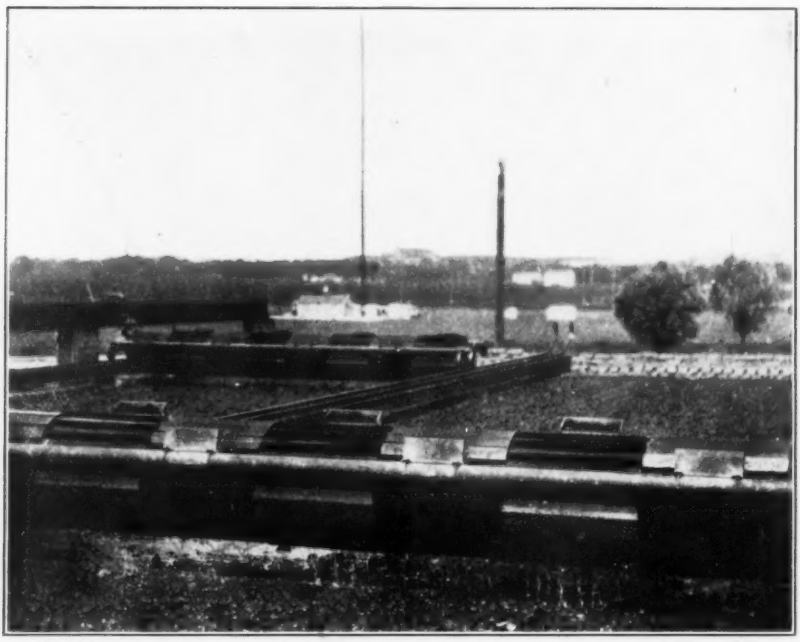


FIG. 6. SEWAGE DISTRIBUTORS SPRINKLING FILTERS, EBERSWALDE, GERMANY

It then passes through contact beds and is finally discharged into a canal.

At Cöpenick, another Berlin suburb, the sewage is mixed with finely ground lignite or brown coal, and a small amount of alum to serve as a coagulant. A very complete mixing is obtained by means of perforated baffles (Fig. 7). The mixing is much more satisfactory than when the baffles were solid. The thoroughly mixed sewage and lignite pass to large sedimentation basins. Much of the suspended matter settles near the inlet. Very little baffling is needed.

and an effluent satisfactory to the government authorities is obtained Three sedimentation basins are provided. While one is in use as a sedimentation basin, in the second the sludge is being dried, and in the third the dried sludge is being removed. The dried sludge is burned for fuel, alone in the furnaces under the low pressure boilers, and mixed with one to two parts of coal under the high pressure boilers, which supply power to the electric light plant of the city.

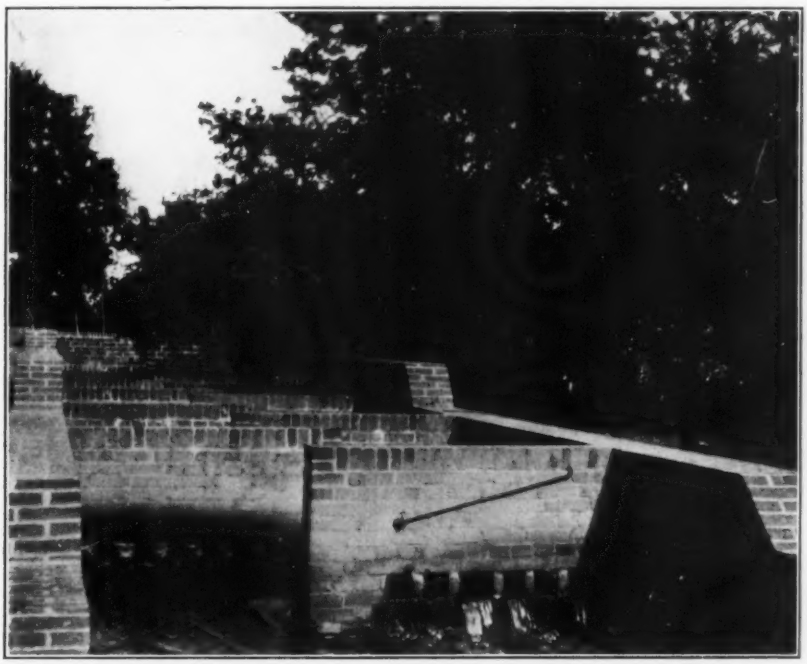


FIG. 7. PERFORATED BAFFLE, CÖPENICK, GERMANY

It is stated that more satisfactory drying of the sludge takes place when it is piled to a height of several feet, than when spread out in a thin sheet, probably due to the pressure exerted on the lower porous layers.

At Dresden the water supply is obtained from wells. Serious difficulties have been experienced because of the manganese content of the Dresden water supply. Service pipes become filled with a black precipitate, and the water cannot always be used for the laundry. Two manganese removal plants are in operation. One consists of

gravity filters built in the original reservoir. The water passes through coarse sand on which manganese removing algae have been developed. These filters are washed by reversing the current, and are probably the nearest approach to the mechanical gravity filters in use in the United States. The second plant consists of pressure filters. One-half are filled with manganese permutit and half with gravel on which a manganese removing organism has been allowed to develop. Both processes are satisfactory, but owing to the economy of the sand and manganese removing organism this process seems to be better than the manganese permutit. A very satisfactory account of the experiments performed at Dresden is given by Tillmans.[5]

Reinsch screens have been recently adopted at Dresden for sewage treatment. The dry weather flow is taken care of by one screen. The storm water sometimes requires four to be put in operation. Without further treatment the sewage is allowed to flow into the Elbe. There is sufficient diluting water to render the sewage innocuous.[6]

No photographs could be obtained of a sewage disposal plant at Coethen, as the plant was visited during a heavy rain storm and photography was out of the question. This plant has been designed by Baumeister Benzel with Dr. Dunbar of the Hamburg Hygienic Laboratory as consultant. By settling ninety-two per cent of the suspended matter is removed, and the sludge is withdrawn before it has time to putrefy. In the bottom are sixteen transverse divisions, each sloping to a trough to which the sediment settles. When this sediment is to be removed, a sliding door separates the trough from the upper part of the tank. The opening of a gate on the side of the tank allows the greater part of the sludge to flow out, the balance is drawn out by means of a hoe. The gate is closed, the trough filled with water and the sliding door opened without any disturbance of the liquid above. The effluent from the tank passes to sprinkling filters which are well constructed with an outside concrete retaining wall of a special design. In the center is a specially designed piece of concrete so arranged that the underdrains can be flushed out with hose whenever desired. Green algae were growing in the effluent drains, showing a very satisfactory purification. Owing to the fact that the plant is new, and that it takes care of both sanitary sewage and

[5] *Journal für Gasbeleuchtung und Wasser Versorgung*, 57, 713–24.

[6] Datesman, *Journal of the American Water Works Association*, Vol. 1, 365.

storm water, and that comparatively few sanitary connections have been made, the plant should receive a more extended trial before the design is unreservedly recommended.

At Magdeburg the Puech-Chabal filters of the Magdeburg water system were visited. Magdeburg has the only large plant of this kind. The authorities are apparently satisfied with it for they are doubling its size. At Magdeburg they use not only the prefilters, but also the socalled rapid filters and final sand filters. It may be necessary to take such precautions with the water from the Elbe, but the installation is certainly very expensive and the cost of filtration must be high. A very good description of these filters is found in *Engineering*, 89, 117, 132, 164.

At Munich the sewage without any purification whatever is allowed to flow into the swift flowing Isar River. Sewage purification is unnecessary because the water below the city is not used for drinking purposes and is too cold for bathing. The engineer stated that within sixty miles all traces of sewage had disappeared. Owing to the outbreak of the war, Munich was the last German city visited.

The cities visited in Germany furnish a good series of illustrations of sewage disposal methods, from straight dilution up to the most thorough treatment.

Owing to the war the London water works were under an armed guard, and it would have been necessary to obtain special permission to visit the plant. Under those circumstances it seemed unwise to ask the authorities for the special favor.

An interesting plant visited in England was the water softening plant of the Woolcombers Ltd. at Bradford, where 50,000 gallons per day of water having a hardness equivalent to thirty grains per gallon were softened to zero by lime, soda and permutit. Permutit alone was not satisfactory and the combined soda ash, lime, permutit plant was installed. The water is first treated with lime and soda, passed through a settling tank, then over calcium permutit to remove the suspended matter and excess of alkalinity. A permutit filter gives the final product of zero hardness. The process is said by the chemist and superintendent to be very satisfactory. Two pounds of soap per grain per gallon per 1000 gallons is the saving made. This is a saving of 60 pounds per thousand gallons.

The largest and probably the only municipal permutit water softening plant is located at Hooten, near Liverpool. This plant was built to furnish a water guaranteed to have less than ten

grains per gallon of hardness. The original water contains about thirty grains per gallon. Two-thirds of the water is reduced to a hardness of zero, and is then mixed with one-third its volume of the original water. Owing to lack of time, the plant was not visited, but, in an interview Mr. Bettle, the superintendent, stated that the process was satisfactory, and that, if it were necessary to enlarge the plant, the same process would be used.

An interesting feature in sewage purification, aëration, was observed at Manchester. The preliminary experiments have been described in the 1914 *Annual Report* of the Rivers Department of the Corporation of Manchester. This process in brief consists in blowing compressed air through sewage until what is known as activated sludge is developed. This sludge added to sewage and stirred by air has the property of purifying the sewage very rapidly. For example, with a tank containing 1300 cubic feet in which are 300 cubic feet of activated sludge, 1000 cubic feet of sewage can be treated every six hours, or 4000 cubic feet of sewage can be treated daily. This allows four hours for treatment, two hours for settling, emptying and filling. It is claimed that by this process a sewage effluent can be obtained which is in better condition than an effluent which has passed through Imhoff tanks and sprinkling filters. If the claims of the process are borne out by further experience, it is expected that considerable sums will be saved in the construction of sewage purification works. Professor Fowler, under whose direction the experiments have been carried out, has consented to serve as advisor for carrying on experiments in the laboratory of the Water Survey. Later his services would be available as consultant for the construction of plants on a larger scale.[7]

To show the stress under which water works men are working, it need only be stated that in one place six rifles were leaning against the wall of the office, and the superintendent stated that the three plants of his company were watched by armed guards night and day. The men in charge of the various plants visited were very cordial, and, even after war broke out, when many of the assistants had volunteered and extra work devolved on those left, most courteous attention was extended.

[7] Ardern and Lockett, *Jour. Soc. Chem. Ind.* 33, 523–39.

THE ACQUISITION OF PRIVATE WATER PLANTS BY MUNICIPALITIES

By B. M. Wagner

The first attempt at a scientific analysis of the above subject seems to have been made by Mr. Wynkoop Kiersted in a paper published in the *Transactions of the American Society of Civil Engineers* in 1897. Mr. Kiersted in that paper foreshadows the now generally adopted idea of a going value in addition to the physical value of the plant proper, as may be seen from the following extract:

> The present value of a plant embraces both the plant and the business resulting from the use of the plant.

Since that time much has been written on the question of valuation, etc., for the purpose of rate making, and comparatively little on the valuation of a plant for the purpose of condemnation.

With the increase of the practice of establishing state commissions having jurisdiction over all matters of public utility, prospects are good for some uniform method of valuation for the taking over of such properties being formulated. At present, where a water works plant is to be taken over by a municipality, it is generally acquired by one of the following methods:

1. Voluntary agreement.
2. By a definite provision contained in original franchise.
3. By due process of law, as where a water works company has violated some of the terms of its franchise.
4. By direct legislative action.
5. By action on the part of the Public Service Commission having jurisdiction.
6. Where a smaller municipality has been absorbed by a larger one, the original rights are nullified.

1. In case of a voluntary agreement it is customary, after the general terms of the taking over have been agreed upon, to legalize such action by a local ordinance, or by a vote of the citizens of the municipality. Such an ordinance usually fixes the number of, and method of appointing official appraisers, etc. The usual practice is

to have three appraisers, one to be selected by each party to the agreement, and the two selected to select the third. As a rule such voluntary agreements provide that both parties will accept as final the decision of the appraisers, and the results will largely depend on the ability and honesty of the men selected.

2. In some states all franchises are limited by law so as to give the community served the right to take over the works of a water works company at any time, upon due notice and after an appraisal, the rules for which are fixed either by the franchise itself or by the laws of the state. Maine and Wisconsin are among the states that provide for such indeterminate franchises. In other states franchises are only granted for limited periods with provisions for renewals or taking. Even when no general state regulation exists it has been the practice in some localities to provide for the contingency of a possible taking, and the method to be followed, by due provision in the franchise.

3. Where a water works company operates under a franchise that contains definite stipulation to pressure, quality of water, service, etc., and it violates any of these stipulations, it can be deprived of its franchise by law, and the community affected can, in such an event, either take over the plant at a legally determined valuation, or it can build its own plant. To quote a case in point:

> In a certain village where the supply was adjudged inadequate, the village obtained not only the right to construct and operate its own plant, but was also given the right to enforce a tax on the offending water company's property for the purpose of installing such a municipal water plant. See Beauty Springs Water Company *vs.* Village of Lyons Falls, New York—134 N.Y., S. 290.

4. Where a water works company is operating under a perpetual, or a long term franchise that has not expired, and the community served by said company desires to acquire the water works property, it can do so by direct action through the state legislature, under what is known as the right of "eminent domain." The United States Supreme Court has ruled that "eminent domain" is superior to franchise rights and that a franchise is merely property, and as such may be taken for the public good, provided that the same is taken in such a manner as will not violate the fifth and fourteenth amendments of the Constitution of the Un'ted States. (Sec. 166 U. S., p. 693 and 115 U. S., p. 673.) In other words, a franchise, perpetual or

otherwise, is property, and has a value that can be legally determined. The franchise as well as other property may be taken for the public good, provided that its owner is paid a legally determined fair value. In law a corporation has the same status as a person.

5. Where a water works plant is taken over under Public Service Commission regulations, it is simply a matter of action under a legislative function that has been delegated by the Legislature to the Commission.

In the Contra Water Company case, the United States Supreme Court decided that the legislature had the right to delegate any of its functions to a commission or other subordinate body, and such commission had in all matters so delegated, all legislative powers when exercised in the manner for it provided.

6. The only case the author can find where a water company lost what it claimed were exclusive rights by the annexation of a community served to a larger political body, was that of the Rogers Park Water Company, operating in a village that was annexed to Chicago. The word "exclusive" appeared in the original franchise, but the Appelate Court ruled as follows:

> But certainly the fact that the life of the corporation which is alleged to have made the exclusive and estopping contract has ceased, that the territory involved has become a part of the city of Chicago, that in consequence the taxing power of the city has extended itself over the inhabitants thereof, and that their property must be taxed equally with all other citizens of Chicago to make up a deficit in the water revenue of the city, if there should be one, does not detract from the force of the argument against the contention of the appellant. It is not possible on the contrary, that the citizens composing the village of Rogers Park, now a part of the city of Chicago have a legal, equitable and moral right to demand that the city of Chicago should give them their water supply on the same terms it gives such supply to other citizens.

No matter what method is adopted for taking over a water company property, the one thing insisted upon by commissions and courts alike is "that the price to be paid must be the fair value of the property taken at the time of taking." Both commissions and courts, however, are very chary of defining strictly what constitutes a fair value. The various elements that enter into a valuation may be defined as follows:

1. The value of the physical plant.
2. The value of the franchise (if any)
3. The going concern value.

4. The market value.

The allowed value may be any one of, or a combination of the above elements, depending upon circumstances and the appraisers.

PHYSICAL VALUE

This may be arrived at in various ways, some of which are enumerated below:

(a) Actual original cost.

(b) Actual original cost, less depreciation and plus appreciation.

(c) Cost of reproduction, new.

(d) Cost of reproduction, new, less depreciation, etc.

(e) Cost by valuation inspection.

In getting at the cost or value of the physical plant, the actual original cost can seldom be ascertained. As a rule a water works system does not come into being as a complete and finished unit, but is constructed piecemeal in a manner that the growth of the community and its demands for water warrant. As the plant begins to depreciate from the moment it is put into service, and additions are made from time to time, it is easy to see that no allowance that does not take into account both of the above factors will be a fair one.

Land value and water rights, on the other hand, may sensibly increase in value, and obsolete or inadequate machinery may be abandoned or scrapped. Taking into account all these factors, the courts and commissions, as a rule, have adoped the "Cost of reproduction, new, less depreciation method," as the fairest to both sides. Such "cost of reproduction" need not necessarily mean an exact duplication of the existing plant. The courts have decided that such cost shall be understood as for a plant of like capacity and efficiency. The most recent ruling of the United States Supreme Court was that the value to be fixed was to be obtained by deducting depreciation from the cost of reproduction, new. Such cost of reproduction may be based on present conditions and prices, or present prices and original conditions, or on original prices and conditions. Marked differences of opinion exist as to which of the above methods is correct.

The courts favor existing conditions and prices, which seems right, as what is sought is the fair value of the property to be taken at the present time. A special committee of the American Society of Civil

Engineers, however, in a report on valuation for rate making, seem to favor using present prices and original conditions. They cite to fortify their attitude the damages, etc., allowed for, apart from the actual price of land, the moving of buildings, and other factors that were met with in the building of the Wachusett reservoir. As indicating the attitude of the courts, however, it may be here stated that, in a recent Minnesota Railroad case, the United States Supreme Court ruled that the value to be allowed for land would be only what other land in the same vicinity was worth now. In an article written by Mr. Alton D. Adams on the valuation of water works, in 1912, he advocates the using of present prices in connection with actual inventory, deducting from the value so obtained the depreciation. He advocates further reductions or deductions in the following cases:

1. No allowance for discarded types of machinery or other equipment of such a nature that no one would think of duplicating at the present time.

2. No allowance for parts of plant abandoned, i.e., not in use because replaced by newer or better equipment. He quotes as an instance a case where an entire pumping station was not valued because it had become inadequate and had been replaced by a larger station.

3. No allowance for mains that are too small to properly perform their functions. He quotes in this instance a case where large amounts of 3 inch and 4 inch pipe were omitted from a valuation as these sizes were considered too small to be of any use whatsoever for fire protection. Other authorities, however, contend that such pipes, if actually in use, must be allowed for.

4. Where the present increased value of land could only be realized by scrapping or removing the plant, and so incurring a loss, he advocates allowing only such value for the land as would cover the cheapest land that could be acquired, in a locality equally desirable and useful for the purpose intended, as the land to be taken. Mr. Adams quotes a case where the land was valued at $150,000, but the court only allowed $15,000 for the purpose of the valuation. As he does not give the details of the case, it may, however, have been a rate valuation.

Depreciation has been defined by a recent writer on the subject as "the lessened money value caused by physical deterioration or by lack of adaptation to function." Needless to say that the measure of deterioration is not always the measure of depreciation. The

methods of arriving at the measure or extent of depreciation are practically the same as are used in rate cases, namely: actual appraisal, calculation on the sinking fund method, calculation on the straight line method. The only one of these methods that seems to be a proper and fair one is the actual appraisal method. Both the sinking fund and straight line methods, with their assumption in the first place of a value arrived at by deducting from the actual cost of sum representing the accummulation of annual cost increments for the past life of the plant or article being valued, are fallacious, and to the author's mind both these methods find their application only in rate fixing. The value as given by either of them is not applicable to purchase cases.

The actual value can best be obtained by an actual personal appraisal, and must be measured by the actual probable remaining life value of the equipment appraised and the scrap value at the end of such life. For instance, a pump or boiler may have theoretically ten years of life remaining, but conditions may be such that it will have to be replaced in a much shorter time, or, on the other hand, it may have been so well maintained that its probable useful life will greatly exceed its theoretical life. In either case only a direct appraisal would be a just criterion of its value.

Appreciation, as a rule, is only possible in the item of land or water rights. In both these cases appreciation, if any exists, should be allowed for. However, in the case of land, values only attainable by losses on other parts of plant should be properly diminished. Discarded or unused plant should be excluded from valuation, or, at the most, its scrap value allowed. The Wisconsin Commission excludes all discarded or unused property except such as is retained for emergency reserve. The court decisions are, in general, to the effect that only property actually used, or useful, in supplying water at the time of valuation shall be valued.

Valuation by direct inspection and appraisal, while it involves in a measure the personal equation of the appraisers, and has, to some extent, fallen into disuse under the commissions, is still used as a check on valuations arrived at by other measures. Book valuation would only be possible where first class continuous written data existed, covering not only first cost, but also the cost of all subsequent additions, and having written off all superseded plant at the time of its being superseded; even then the depreciation would have to be accounted for.

THE VALUE OF THE FRANCHISE

The value of the franchise, where any exists, is nowadays apt to be considered as part of the Going Concern Value, but, as cases have arisen where franchise value as such has been given separate recognition, it may be well to take it up as a separate factor.

A franchise to have any value must have a definite life, and must provide for privileges to the holder that have an actual value. A franchise with only a few years to run, and that permits of a rate regulation, or that is revokable at will or is otherwise subject to regulation, has but little, if any value; on the other hand a perpetual or long term franchise with a fixed scale of rates, that allows its holder to earn an income, giving a large rate of return on capital actually invested, has a value that must be allowed for in a valuation of this kind.

The courts have decided that a franchise is property, and its fair value must be paid when taken for the public good. Various states have different methods of dealing with the Franchise Value question. In Massachusetts municipalities are granted competing franchises unless the water companies agree to sell on such terms as will exclude franchise values. In Wisconsin many water companies have voluntarily given up term franchises for indeterminate commission permits, which, while they secure the companies against competition, cannot be capitalized in cases of municipal purchase.

The date on the life of franchises given in Table No. 1 should be of interest as bearing on the possible franchise value in different states.

GOING CONCERN VALUE

Apart from the value of an operating water works plant as a physical unit, there exists a certain value due to the fact that it is operating, has customers and an income; this value is what is known as "going concern value."

Such a value may or may not, as the case may be, include the franchise value, but in any case it exists independent of a franchise value. Table No. 2 gives a few decisions that have been made on the subject of various valuations, but it is only fair to say here that the tendency nowadays is more and more towards recognition of such going value. The actual measure of this going value is, however, a subject of dispute. Mr. J. W. Alvord states, "going value is the value of the created income, or the cost of reproducing a given

income." Mr. Benezette Williams states, "Going value is the potential business value, the amount of which must be determined by the net income which a plant in operation can produce in excess of what a substitute like plant can produce." Mr. Williams and Mr. Alvord agree that the going value is the value of the created income, but differ as to the method of arriving at such value.

The Wisconsin Commission in the Antigo Water Company case, August, 1909, decided that the going value should be measured by actual investment rather than by a valuation of the created income. Mr. Alvord uses what is known as the comparative plant method. In other words he assumes a new plant just starting, and figures what it would have to expend, and what the existing operating plant will receive before the new plant arrives at the same measure of income as the existing plant has.

The New York Public Service Commission, First District, disapproved the comparative plant method. The United States District Court, in a San Francisco rate case, also disapproved the comparative plant method.

The general premises on which going concern values have been based are as follows:

(a) Estimated deficits that would be incurred before a new plant could equal the present business of the established plant.

(b) Estimated deficits that would be incurred before a new plant would be on a paying basis.

(c) Actual deficits that were incurred before the existing plant was brought to a paying basis.

(d) The same as (c) except that from it be deducted all amounts over a fair rate of return on actual investment that the plant has made since it has been on a paying basis.

None of the above rules have any particular court sanction. In most cases the courts have merely made an allowance for going value, but have not in any way indicated by what process their decision was arrived at.

The Wisconsin Commission in the Antigo case used a method based on the rule that "certain costs of development in the first years of a plant's existence may be added to the plant cost charge, and form the 'going concern value.'" The method was as follows:

Beginning with the first year the plant was charged with cost, new extensions, interest, depreciation and operating costs, and credited with the gross earnings of the year. The balance was carried

forward to the second year and the process repeated, and so on for each year of the plant life. The balance, at the end of the last year considered, was regarded as the value of the plant on an earning basis at the end of the period.

In 1911 in the case of the city of Marinette *vs.* City Water Company, the commission decided that the amount by which the earning value exceeds original cost plus extensions is to be taken as the measure of going value. The commission states, however, that not all failures to earn a fair income shall be capitalized as going value. The rule must be applied with care, and must not be taken to include losses due to poor judgment or to lack of ordinary care, foresight and efficiency. The Wisconsin rule, so far as the author can find, has not been put to court test.

In a recent case of "taking," involving a street railway valuation, Mr. B. J. Arnold used the following as one of the methods of getting at the value of the property taken. It is along the line of the method adopted by the Wisconsin Commission, and Mr. Arnold states that it has been used abroad in railroad condemnation cases. The method is as follows:

Take each year the actual investment in the property, deduct the value of all superseded property in the year it was superseded, and estimate what would be a fair return on the net investment. Deduct from such return the net income after paying operating expenses, including maintenance, renewals and taxes, charging to operating expenses all superseded property in the year it was superseded. Then, compound each year the deficit or surplus, as the case may be, between the fair return and the actual net income. The result will be a sum of the accrued losses estimated upon the return at a given reasonable per cent. The total accrued loss plus the physical value will be the fair value of the property.

In general the courts have based their decisions on the value of an established business rather than on the cost of establishing the same as measured by past losses.

Where a water company is operating under a fixed rate franchise, the franchise and going concern values become one, and the value itself may be based on a capitalization of its excess income. Going concern is not considered as representing what is known as goodwill. The highest court in this country has held that, from the nature of the service, a water company is virtually a monopoly, and, as such, no goodwill can exist.

The following examples of actual decisions by the Wisconsin Commission may be of interest:

FOND DU LAC WATER COMPANY, AUGUST 19, 1910

Cost of reproduction, new	$314,439.00
Cost of reproduction, new, less depreciation	281,922.00
Original cost, plus additions to 1910	310,165.00
Earning value at 6 per cent (Market Value)	307,166.00
Commission allowed	320,000.00

APPLETON WATER WORKS COMPANY, SEPTEMBER 7, 1910

Cost of reproduction, new	275,781.00
Cost of reproduction, less depreciation	240,168.00
Commission allowed	255,000.00

MANITOWAI WATER WORKS COMPANY, JUNE 27, 1911

Cost of reproduction, new	$242,510.00
Cost of reproduction, new, less depreciation	223,108.00
Original cost, plus additions to 1910	233,183.00
Earning value at 6 per cent	231,357.00
Commission allowed	236,000.00

The market value of a plant where used includes all elements that go to make up the value of the plant as a business, and is generally based on its earning capacity.

Where a long term or perpetual franchise with fixed rates is involved, the market value seems to be the only reasonable basis for an award. In other words, if, by reason of its franchise, a water works company was allowed to charge rates that gave it a return of more than 6 per cent on its actual outlay, over and above its operating expenses, taxes, depreciation, etc., such surplus income, for the purpose of its unexpired franchise, would have a definite value that would have to be paid for. As a case in point, the following railroad case is quoted, the principle involved being the same:

Mr. B. J. Arnold in the Metropolitan Street Railroad case, 1913, based a value on the following premises:

(1) Rights that now exist will last to 1925.

(2) Net profits for each year estimated by the following method:

(a) Gross receipts, less operating expenses (which include maintenance, depreciation on present value and taxes).

(b) Less fixed interest charges upon depreciated tangible value of the property as then found.

The net returns thus found are discounted at 5 per cent per an-

num, to get present value. From this value deduct the present value of the future interest charges that must be met to supply the constantly increasing capital needed to produce future earnings. The net result is the present going concern value.

INVENTORY

The matter of making an inventory of the physical property of a water works plant can be divided into two divisions which may be roughly classified as field and office work.

The field classification covers the listing of all property that can be actually visualized in the field. Where prices are affixed in such field lists, they must be considered merely as supplementary information, and should, in no case, be used by the office force for final results unless properly verified.

To simplify the field work and insure uniformity of results, proper blanks should be prepared for the use of the field force, covering the various classes of items that are to be listed. As models for such blanks or forms, the forms used by the Wisconsin Commission for this purpose are suggested, as they are probably the best now in existence. All field notes should be kept in duplicate, preferably by using carbon sheets for making duplicates. The original sheets should be turned in to the office force at intervals not more than one week apart, and the duplicate retained by the field force. A proper system of numbering should be used, and each article listed should have its number plainly marked on it, to prevent confusion or duplication. In the event of further information being obtained about an article listed, or errors being discovered in a like case, corrections should be made on the field copy, and the office notified on a special form as to the corrections to be made, giving serial number, etc.; carbon copy of such correction sheet to be held by field force and attached to its records. In all cases condition of article should be noted, and, in the case of supplies and tools, the designation might be, new, used, still usable, and scrap. In listing machinery, boilers, etc., the Wisconsin classification of G, F and P may be used to advantage. In the Wisconsin code "G" indicates that the item is to be depreciated for age only; "F" indicates a 90 per cent of "G" value, and "P" indicates an 80 per cent of "G" value.

While the field force is organizing and getting started, the office force should be employed in making up as far as possible a separate

inventory from such records as are available. This inventory will serve as a check on the work of the field force; in the case of any glaring discrepancies try to obtain an explanation or adjustment of the same.

Some items will probably only be obtainable from the records. The office force must also prepare lists of standard prices that will be applied in making up the costs to be adopted. After the lists are all made up, prices applied, extensions made and preliminary summaries compiled, it would be well to have the main items looked over in the field by experienced engineers, to determine the actual depreciation as compared with that determined by the field observers, or computed by the office force.

The determination of the proper prices to be used, and extent of depreciation, are the two most delicate factors that occur in the physical valuation, and must be handled with care. To cover errors and omissions it is the custom nowadays to add an allowance of from 5 per cent to 15 per cent of the total inventory value to such value.

The various factors that make up the inventory are briefly as follows:

Mains, valves, hydrants, etc.

For a schedule of mains the records will, as a rule, have to be depended upon; the valves and hydrants can be checked up by the field force. The field force will have to note condition and class of pavement, supervise such excavations as are made for getting at depth of cover and condition of mains. The office force will have to make up the schedule proper, and get what additional information is required in the matter of pavements. Where grave discrepancies between records and field notes exist, or where no records are available, it will be necessary to get at the facts by actual location of gates and hydrants in the field with excavations at intervals to determine sizes of mains. Cost of such extra work should be charged to the water company.

Structures

All large structures such as filters, reservoirs, intakes, etc., will, in case plans or records of their construction are in existence, have such plans or records checked by the field force. Where no plans or records are available, the field force will be required to make such surveys and notes as are needed in order to get at quantities. Con-

ditions must be noted in all cases. It may be noted here that it is more than probable that, in the absence of records, the cost obtained will be less than the actual original cost.

Buildings

What has been said about other structures holds good for this item also. In no case should the cost or value assumed be based on cubical contents only.

Boilers, machinery, pumps, etc.

Each boiler pump, feed pump and main auxiliary should be listed separately. All steam piping, fittings, valves and pipe covering should be listed separately as to size, condition, age, and all obtainable information should be noted carefully. All suction and discharge piping should be listed in detail. Foundations for boilers and machinery should be listed in detail, with particulars of nature of soil, ground water elevation, etc.

Driven wells

Where driven wells form the source of supply, the field force can do but little more than get the number of wells, etc., size of casing and total depth. If no records are available on size, length and nature of strainer, a very small allowance should be made for same. It might, in some cases, be necessary to withdraw and redrive a well in order to settle disputed points.

Supplies, tools, etc.

Items under this heading should be listed as far as possible in bulk; where new, by original packages, and where in use, an average condition should be determined for each class of article.

Land

As a rule this item is taken care of by the office force, but the field force should be instructed to note character of adjacent land, nature of improvements, etc. As to prices or values the engineer must needs depend upon the expert opinion of nearby real estate

appraisers. The socalled "Sales Method" sometimes used for getting at values is merely a systematic collection of data, and comparison of the same, based on the records of sales, transfers, etc., of property in the neighborhood of, and having like conditions as the land to be appraised. Two interpretations of this method are used, the one being an average unit price per acre, lot, etc., such unit price being applied to the like unit of property to be valued; the other interpretation being based on same data, but comparing the assessed values of the known and the to-be-valued properties.

Water rights

These are in most cases bound up with land values, although in some cases a separate distinct value may be in order. In case of a large supply taken from a large lake or river that is equally available for others, no water right value can exist; on the other hand, if the water company controls the only nearby source of supply, or has, by reason of franchise rights or special laws, a practical monopoly of the only reasonable source of supply, a value exists that will probably have to be paid for.

Intangible values

Apart from the value of the physical property, every water works plant has an intangible value that may be composed of one or more factors of its existence. The determination of such intangible value is the hardest problem that faces the appraiser, and it is not easy to give any fixed rules for this purpose. As to the main factor, the socalled "going concern" value, the recent decisions of the courts seem to indicate that it is the present measure of the business value, and not what it actually cost to establish the business. If this view be taken the method proposed by Mr. Alvord probably will fix the lines along which the appraiser will work. On the other hand, if the actual cost of establishing the business be taken as the measure of its going value, the method used by the Wisconsin Commission in the Antigo case will probably be followed.

Where a direct value exists, such as a net income over and above all operating interest and other charges, due to a franchise that fixes rates, the present value of such income for the remaining life of the franchise is easily determined. While very little discrepancy need exist in physical values arrived at by different appraisers, the

speculative elements that enter into the determination of intangible values are of such a nature as to make it a very hard matter for even the fairest minded appraisers to agree on such intangible values.

CONCLUSION

In general, the acquisition of a water works plant by a municipality, whether it be by agreement or condemnation, is in its last analyses analagous to the purchase of any other mercantile business. The stock in trade, apparatus, fixtures, etc., in either case are inventoried and valued at what they are supposed to be worth at the time of purchase, and not at what they may have cost, or may be worth at some future date. The land values are taken as they exist, and if, by reason of special location or fitness, such land has a greater value than adjacent property, such value is paid for. The goodwill of the private business finds its counterpart in the "going concern" value of the water works, and if finally, by reason of some special process or patent, the private business has a special additional va such value also exists for the water works company that has a franchise fixing rates that give it more than a normal return on its investment, and in both cases such special values must be paid for.

TABLE NO. 1

FRANCHISE CONDITIONS IN VARIOUS STATES

New Jersey:

Franchise life limited to thirty-three years, but may be made sixty-six years by a majority vote of the votes of the district or town involved.

Greater New York Charter:

Franchise life on original grants to be not more than twenty-five years. A renewal of twenty-five years at a valuation is allowed.

Illinois:

Maximum franchise life twenty years.

Ohio:

Maximum franchise life twenty-five years.

Michigan:

Maximum franchise life thirty years. The New Michigan constitution provides that all franchises granted, except such as may be revoked at will, require the affirmation vote of 60 per cent of the electors of the city granting the franchise.

Massachusetts:

Any franchise may be revoked at any time after the expiration of one year from the date of the franchise.

Wisconsin, 1907:

All future grants and all authorized companies that surrender original grants are to receive indeterminate franchises.

New York State:
In 1892 the franchise term for all water supply companies on franchises granted by municipal officers was made ten years.
District of Columbia:
Indeterminate franchises.
Porto Rico:
Indeterminate franchises.
Maine:
Indeterminate franchises.
Philippine Islands:
Indeterminate franchises.

TABLE 2

GOING CONCERN VALUE DECISIONS

1. Kansas City Water Works: United States Circuit Court of Appeals in 1894. Added for established business to value to be paid. This is the leading case in such matter.
2. Gloucester, Massachusetts: Water Plant Purchase, 1899–1901. Allowance made for Going Concern Value.
3. Bristol, Rhode Island. Water Plant Purchase, 1901. Going Concern Value not allowed.
4. Mobile, Alabama. Water Plant Purchase, 1903. Going Concern Value not allowed.
5. Galena, Kansas. Water Works Purchase 1910. Going Concern Value allowed.
6. Maine, 1902 and 1904. Going Value allowed.
7. Omaha, Nebraska. Case, May 31, 1910. United States Supreme Court, 218 U. S. 180, 30 Sup. Ct., 615, 54 L. ed 991. Going Value was allowed.

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THE CINCINNATI WATER WORKS

By John W. Hill

In the following brief paper on the Cincinnati Water Works it is not intended to do more than roughly sketch its history and call attention to some of the more interesting events in its development.

Unlike many city water works constructed at later date, the public supply of this city has gone through all stages from the leasing to consumers of a "privilege" to raise ground water by windlass from a privately owned well to the pumping of water from the river by the highest type of engines, and delivering this after elaborate filtration, under pressure, to the consumers.

"Water works" of the primitive kind were established in this city as early as May, 1799, long before cast iron pipes, high duty pumping engines and filtration were known. But at that date the sources of supply were either springs on private property or shallow dug wells, from which the consumer drew his water supply into a bucket or barrel and carried or hauled it to his home. The enterprising citizens who owned good springs, or wells, were careful to make a charge for the use of water from them, and in one instance the owners of a well charged as much as four dollars per year to each consumer for the water privilege, the consumer being required to furnish the motive power to turn the windlass and raise the water from the well. This charge nearly, if not quite, reaches the minimum charge in some of our cities today, where the water is delivered to the consumer through cast iron pipes under pressure.

The privately owned supply for public uses did not continue long, for early in the past century (1809) wells were dug at various places about the town and equipped with windlasses, ropes and buckets, and the cost of these was assessed on the real estate tax duplicate.

The labor of raising water by a windlass did not appeal very strongly to our municipal ancestors, and soon this method of public supply was exchanged for a barrel or tank mounted on wheels and drawn by horses or oxen. The tank wagon was hauled down to the river and filled with a long handled tin ladle, and when full the

carrier distributed the water to his customers. A large number of these water venders doubtless were required to supply the necessities of the town; but this method was the most advanced for the supply of public water until July, 1821. It will be noted that the method of public water supply of the town, if it can properly be called such, was quite like our milk supply at the present time. For a period of about twenty years the water was hauled from the river and delivered to consumers by these tank wagons. The per capita consumption must have been small; but the cost per gallon delivered must have been relatively large, when compared with the modern cost of purveying public water supplies.

Other cities than Cincinnati have been compelled in their early history to depend upon tank carts and wagons for the daily water supply, and it may be of interest to note that our late lamented member, Mr. Emil Kuichling, employed this method of water delivery in estimating the value of Spot Pond Reservoir to the Boston Metropolitan Water System, assuming that the equivalent of the Spot Pond gravity supply through pipes could be obtained by water delivered to the consumer by water venders, and that the value to the Metropolitan System of the natural supply at an elevation above Boston, etc., might be determined in this primitive way. Of course the value thus obtained was high, in fact several times the amount reached in their decision by the board of auditors (Messrs. Benton, Bumpus and Stiles).

The growth of population and demands for water having outrun the "Mosaic" method of supply, one of the enterprising citizens, a wagon maker by the name of Reeder, devised a crude chain pump, mostly constructed of wood, with which he lifted the water from the river and delivered it into a shallow wooden oblong tank containing about 40,000 gallons. But this small body of water in an open reservoir exposed to the sun soon became stagnant and the public refused to buy Reeder's water, and cast about for a more modern method of supply for public uses.

At that time (1817) one of the foremost men in Cincinnati was a Mr. Samuel W. Davies, who was associated with a Mr. Jacob Findley in a woolen-mill, a white lead works and some other early manufacturing operations, under the title of The Cincinnati Manufacturing Company, and to Mr. Davies the Town Council went with an appeal to establish a power pumping works and distribute the water through pipes to the consumers, and also to erect pen-

stocks (fire hydrants) on the lines of pipe for fire protection. In due time an ordinance was passed giving Mr. Davies and his associates a ninety-nine year franchise with no restriction on the charges for water for domestic uses, and no compensation for fire protection. In addition, Mr. Davies and his associates were required to pay the town one hundred dollars per year for the franchise.

The charter of the company, one of the earliest written for a privately owned water works in this country, is brief, and for the benefit of those who may not know how such things were done a hundred years ago, it is here quoted in full.

The ordinance or charter reads as follows:

Section 1. Be it ordained by the Town Council of the town of Cincinnati, That the Cincinnati Manufacturing Company, their heirs, successors and assigns, shall be, and they are, hereby vested with the exclusive privilege of conveying water, by tubes or otherwise, from the Ohio River, through the streets, lanes and alleys and commons of the town of Cincinnati, for the purpose of supplying the inhabitants of said town therewith; which privilege may and shall be enjoyed by the said company, their heirs, successors and assigns, exclusively, as aforesaid, for the term of ninety-nine years from and after the passing of this ordinance, on the following terms:

1. The said company shall complete the work so far as to convey the water into that part of the town lying south of Third Street, commonly called the bottoms, within two years from and after the first day of July next; and they shall convey the water into that part of the town lying north of Third Street, commonly called the hill, so that same may be delivered three feet above the first floor of James Ferguson's kitchen, in the second ward of said town, within the term of three years from and after the said first day of July.

2. After the said period of three years, the company, their heirs, successors and assigns, shall continue to supply the citizens of the town (or such of them as may desire to receive and pay for the same) with a sufficient quantity of water, making proper allowance for unavoidable accidents and for the necessary repairing and renewing of their works.

3. They shall permit water to be taken freely and without expense from their reservoirs and conductors, wherever the same shall be necessary to extinguish fires in the town, and for this purpose they shall provide for each square or block to which they conduct the water a fire plug or pen stock; and, if the Town Council shall at any time see proper to make reservoirs to be used in cases of fire, they shall be permitted to fill such reservoirs, free of expense, from the conductors of the company: Provided the said reservoir be kept tight and in repair, and the water therein be used exclusively for the purpose of extinguishing fires.

4. The company, their heirs, successors and assigns, shall pay to the Town Council, yearly, and every year during the continuance of the privileges herein granted, the sum of one hundred dollars, which payment shall commence one year after the works are completed. The money so to be paid

shall constitute a free fund, and shall be appropriated under the direction of the Town Council, in such manner as they shall see proper, in providing and preserving such articles as may be useful in extinguishing fires.

5. The said company, their heirs, successors and assigns, shall be permitted to dig in the streets, lanes, alleys and commons of the town, for the purpose of sinking their conductors and repairing them as often as may be necessary, leaving the surface of the streets as before, causing as little inconvenience to the citizens as the nature of the case will admit; and they shall be permitted to demand and receive yearly, from the persons who shall use the water from their conductors, such sum as they may voluntarily agree to pay for the same.

6. The privileges granted by this ordinance shall not be forfeited by a temporary interruption in the supply of water occasioned by accident, or the want of repairs in the machinery, reservoirs, conductors, or other parts of the works: Provided, such accidents be remedied, and such repairs be made, within a reasonable time.

7. During the term of ninety-nine years hereinbefore specified no other person or company shall be permitted to convey water through the streets, lanes, alleys, or commons of the town by tubes or other conductors for the purpose of supplying the citizens of the town with water.

Section 2. Be it further ordained, That if the charter of the said Cincinnati Manufacturing Company shall expire, or the said company be dissolved before the expiration of the aforesaid term of ninety-nine years, this ordinance and the privileges herein granted shall not hereby cease, but shall continue in full force and effect, and at the dissolution of the said company all the privileges herein granted shall vest in the persons composing the said company, at the time of such dissolution, their heirs and assigns, in the proportion of their several interests in the stock of said company; Provided, the persons claiming the privilege aforesaid comply with the terms hereinbefore mentioned.

(Passed 31st of March, 1817.)

Several interesting points are here presented.

1. The great length of the grant, which if it had not lapsed by reason of purchase of the works by the city (1839) would not expire until March, 1916, or about one year from the present time.

2. No schedule of water rates was agreed upon and Mr. Davies and his partners held that there was no limitation to the water rates they could enforce, excepting the patience and forbearance of their customers, all of whom could return to the old cart method of supply if the Water Company became exorbitant in its charges. It does not appear, however, that Mr. Davies was at any time unreasonable and as he financially failed in the enterprise, it would seem that he really pumped and distributed the water without profit.

Of course it is known that a charter was granted to a company in New York about the year 1800 for supplying water through pipes to the inhabitants of that city, and that a pumping station and small elevated tank had been erected in Center Street, and a small amount of pipe laid, in order to comply with the letter of the charter, but with no real intention of supplying water to the city. The purpose being to establish a United States Bank, rather than works of public water supply. Alexander Hamilton and Aaron Burr were members of this earlier New York Water Company. The ordinance, or charter, for the Cincinnati Water Company, however, was a bona fide instrument for the purpose of authorizing and protecting a works of public water supply and had no other motive than the supply of water for domestic uses and fire protection in the embryo city.

Some of the provisions will appear very curious to us at this distant time, for example, the limiting head to which the water shall be pumped is determined in Paragraph 1 of Section 1 of the ordinance as follows, viz.:

"Three feet above the first floor of James Ferguson's kitchen in the second ward of said town."

The location of Mr. Ferguson's residence is not specified, and if he should happen to move from one part of the ward to another at higher elevation, during the construction of the works, or perhaps even after the works were constructed, the Water Company under the ordinance would be required to increase the pressure at which the water was delivered through the mains. In other words, no fixed elevation is given.

Upon the other hand, if James Ferguson should happen to move out of the second ward altogether, before the works were finished, no limiting head or pressure is then specified in the ordinance.

Paragraph 5 of Section 1 provides that:

"They (the water company) shall be permitted to demand and receive yearly, from the persons who shall use the water from their conductors, such sum as they may voluntarily agree to pay for the same."

This is the nearest approach to a schedule of domestic water charges in the ordinance, or charter, and it doubtless led to quite a variation in the amounts charged consumers according to their ability and willingness to compensate the company for the water taken.

By paragraph 7 of section 1 it will be noted that the town council granted an exclusive privilege to Mr. Davies and his associates to occupy the streets and highways with water pipes and to supply water to the citizens of the town.

A wood cut of this first power water works for the city adorns the stationery of the local committee for this convention. This cut was drawn from a published description of the Davies Water Works at the time they were started in service (1821), and it is only fair to remark that one of the members of the local committee, Mr. Pollard, took exceptions to one feature of the cut which in his judgment did not represent good engineering practice even in 1820.

The cut is here produced for the edification of our members, and attention is drawn to the bank of earth extending out over the edge of the river, upon which Mr. Davies built the foundations for his pumping station, and by piercing the earth put the suction of the pumps into the water. The fault or mistake is to be charged to the draughtsman (1880) and not to Mr. Davies, who we are assured from his well known enterprise and intelligence never built his pumping outfit in that way.

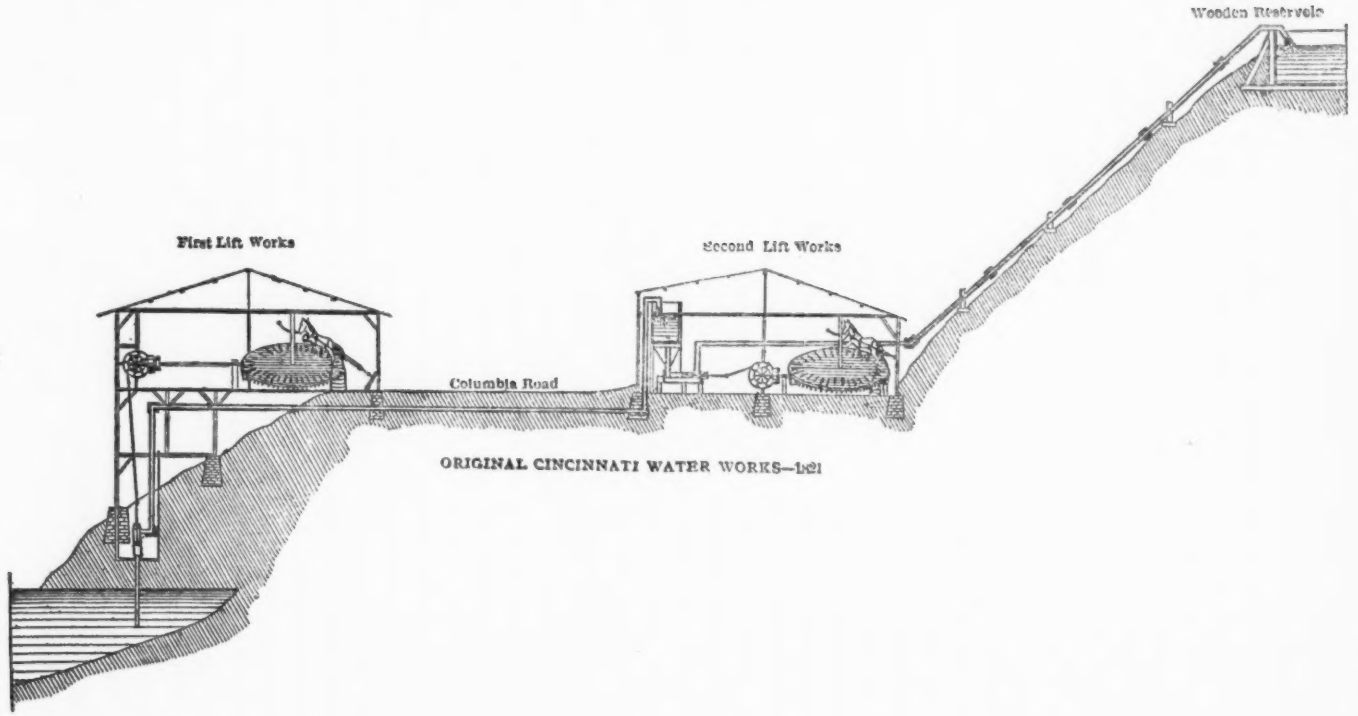
The Davies distribution system consisted of white pine and white oak logs through which was bored with a pod-augur one and one-half inch and two and one-half inch holes. These logs were banded at one end and put together stove pipe fashion by driving the spigot into the banded bell or socket.

There are no records showing how the hydrants were made, excepting that the "pen stocks," so called, were of wood.

The pumping machinery consisted of one low lift suction pump, which lifted the water from the Ohio River to a tank in the pumping house, and a so-called force pump which took the water by gravity from the tank and pumped it to an elevated wooden service reservoir. From the reservoir the water flowed by gravity through the wooden pipes laid in the streets.

The motive power to operate the pumps were horses or oxen working on inclined treadmills, and the engineer was a boy or man who regulated the power according to the demands for water.

This was the beginning of the Cincinnati Power Water Works. The service was not satisfactory, and many complaints were made on account of the frequent breakdowns, and interruptions of the public water supply, and yet at that time as the census shows the population and demands for water under pressure, or running water,



ORIGINAL CINCINNATI WATER WORKS—1821

were increasing from year to year by leaps and bounds, because this city was then the foremost "settlement" west of Philadelphia, and being located on a great highway of commerce the surplus population from the Atlantic seaboard cities flocked here in great numbers during the earlier years following the second war with England.

About three years after the works were started in service, Mr. Davies installed a steam pumping engine of 1,200,000 gallons daily capacity which probably he himself designed. The steam cylinder was twelve inches diameter by five feet stroke, and the two low lift and two force pumps which it worked were each six inches diameter by four feet stroke. The engine was rated at forty horse power.

In 1828 this pump was remodeled by Mr. Anthony Harkness, who was, for the pioneer days in this section of the country, in several ways a marvel. He was one of the first to establish a foundry and machine shop to build engines for western steamboats. He saw and remedied the defects in the first steam pumping engine (Davies) ever started in Cincinnati. He designed and built the first locomotive in Cincinnati, and more than sixty years ago went abroad to obtain contracts for locomotive engines of which he was then a successful builder. Robert Fulton invented the steamboat in 1807, and not many years afterward enterprising men were busy in the West, especially here, in adapting it to the requirements of the western rivers. Among these was Mr. Harkness, and it was doubtless on his advice that the steam end of the first pumping machine was taken from a steamboat and utilized for pumping water.

We are much concerned today about the unnecessary waste of water, and are seeking by every available means to prevent or reduce it. In fact, this is the chief argument for the use of water meters, and you may be surprised to hear that the leading trouble with Mr. Davies' Cincinnati Water Works (1824) was the large unnecessary waste of water.

This needless waste of water from works of public supply has continued over a long stretch of time; it has reached from Frontinus A. D. 92, to John C. Trautwine, 2nd, 1900, and the same complaint that we are putting up today, that Mr. Trautwine put up in 1899, and that Frontinus put up to the Emperor Vespasian in 92, is still a condition to be wrestled with, and by the sympathetic and energetic efforts of the meter men may some day be laid at rest.

Mr. Davies finding that his water works would not pay, and discovering as others since have discovered, he could not borrow himself out of debt, offered (1824) to sell his works to the city for $30,000.

The Town Council appointed a committee to examine the works and books of the water company and report on the advisability of buying the property. The committee reported favorably, but upon taking a vote, 25 freeholders were in favor and 294 against purchase.

In 1826 the water company had its charter powers enlarged by Act of the Legislature, additional capital was obtained, and Mr. Davies, who must have been an enthusiast on water works matters, set about to remedy the defects and deficiences in the works, and adapt them more nearly to the requirements of his time.

Between 1825 and 1832, three new reservoirs were constructed on the site of the old Third Street Reservoir, just north of the old Front Street Pumping Station. The first line of cast iron water pipe was laid from the distributing reservoir in Pearl Street, west (1828). This pipe was of unusual size, viz.: eight inches diameter, and must have been obtained at that time from R. D. Wood and Company, who had started the first pipe foundry in this country a few years before at Millville, New Jersey. Incidentally it may be mentioned that this firm is still supplying cast iron water pipe, upon sufficient provocation, to those who may need it.

The unhappy condition of Mr. Davies' finances, the unsatisfactory water service to the city, and the many complaints from the injured water takers, led to another effort by the Town Council in 1832 to purchase the water works and relieve the water consumers from some of the handicaps which they had suffered since the works were installed eleven years before. The committee appointed again reported in favor of purchase at a cost of $150,000, or five times the cost for 1824, and again the "harassed" and "indignant" freeholders and water takers voted against the purchase by a vote of 303 "for" and 617 "against."

The water company then increased its capital stock and proceeded to "enlarge the works commensurate with the rapidly growing needs of the city." To do this the company was required to appeal to the state legislature for enlarged charter powers, a proceeding which the city council at first opposed. After a lapse of three years, the council withdrew its objection, the legislature

granted the additional powers asked for and the water company started on a new career of "progress and trouble." In 1835 the water service being still unsatisfactory, the council appointed the third committee to investigate and report on the advisability of "municipal ownership" of the works. This committee reported favorably on purchase at a cost of $273,637—(note the first offer in 1824 at $30,000),—and the vote when taken stood 956 "for" and 1274 "against."

Two years later, 1837, the "purchase" was up again and this time the vote was 1573 "for" and 531 "against." Owing to some defect in the proceedings for the vote, a new vote was taken, March, 1839, on purchase at $300,000, with the result of 728 "for" and 553 "against."

In 1839 therefore after a stormy and financially disastrous career of eighteen years, the Cincinnati Water Works became a municipal institution.

When the purchase occurred the property consisted of a tract of land including the site of the late Front Street Pumping Station and the Third Street reservoir grounds, now a public park. It will be noted that the city had a population in 1840 of over 46,000, while the combined pumping capacity was rated at 4,200,000 gallons per day, showing a maximum possible capacity of about 90 gallons per capita. It is probable that the actual water consumption was much less than half of this quantity, because the larger pump must have been out of service at times for repairs, when the smaller original machine, if it maintained a supply equal to the normal consumption, would have furnished less than 30 gallons per capita.

A stone masonry reservoir about 350 feet long, 50 feet wide, inside surface dimensions, and 12 feet deep, containing 1,200,000 gallons, had been constructed on the Third Street property as early as 1828. The pumping lift from the Ohio River, low water stage to the flow line of the reservoir was about 160 feet.

It must be remembered that the two earlier steam pumping machines were built during the pioneer days of pumping machinery in this country. The first engine (1824) was of the walking beam type with a wooden walking beam. The second engine had the steam cylinder located axially over the pump and drove the pump direct.

The earlier pumps were all of the piston type with swinging or "barn door" water valves resting on seats inclined at an angle of

45 degrees. Everything about the water ends was plain, direct, simple and crude, and yet these old machines contributed largely to the early development and prosperity of the city.

The property conveyed to the city contained:

(1). The land above mentioned.

(2). The pumping station.

(3). Two rotative steam pumping engines.

(4). The masonry reservoir.

(5). Nineteen miles of wood pipe or "logs" from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches diameter of bore.

(6). Three and one-half miles of cast iron pipe varying from 4 to 20 inches diameter.

Looking over the inventory of property it would strike one at first sight as though the price was more than it was worth. But the people were satisfied, and it would be presumption for us at this distant date to criticise the acts of our forefathers. In 1840, the population of the city was 46,338 and the purchase price was about $7.00 per capita of population.

When the city took over the water works the following survey rates were adopted:

Lowest consumption	$10.00 per annum
Second consumption	$12.00 per annum
Third consumption	$14.00 per annum
Fourth consumption	$16.00 per annum

Baths $3 each, hose $1, Garden sprinkling $1 to $4.

The works were very wasteful of fuel and steps were taken to investigate a possible water power from the Miami and Erie Canal near its entrance into the Ohio River just below the pumping station; but upon investigation it was found that the proposition was not feasible.

Several years before the water company sold its property to the city, a new pumping engine from original designs was built by The A. Harkness Company of Cincinnati. This "power" as it was termed had a capacity of 3,000,000 gallons per day pumped from the Ohio River to a reservoir on the site of the old Third Street Reservoir. This reservoir, abandoned in 1907, supplied by gravity the district lying between Fourth Street and the river. The first two steam pumping engines installed by the water company (1824–1834), were vertical crank and fly wheel machines with the water ends

set low enough to take water by suction from the river at its lowest stages, and the steam ends placed high enough to be above all ordinary flood stages in the river. The maximum flood stage of record is more than 71 feet above low water mark, and it will thus be seen that the steam ends of these pioneer pumps must have been set about 50 feet above the water ends.

After the purchase of the works by the city a new duplex steam power was built (1844) which consisted of a pair of crank and fly wheel steamboat engines on inclined frames driving vertical pumps. These pumps had a combined capacity of 5,000,000 gallons per day and after various changes in the steam valve gear became and remained for years the most useful and economical machines in the Front Street Station. They were taken out of service during 1907 after sixty-three years of useful life.

Passing over the details of water works improvements under city management from the purchase in 1839 to 1865, we come to a period following the war of the states, when it was evident that the works were in need of a general and comprehensive rehabilitation. During this period the two original pumping engines were abandoned and their places taken by two vertical condensing crank and fly wheel steam pumping machines, each of 4,500,000 gallons capacity (1850–1854) constructed from designs of Mr. T. R. Scowden by The A. Harkness Company and Powell and Sons, of Cincinnati. These engines were marvels for their day and with some changes in the water ends continued in active service until the Front Street Pumping Station was abandoned (1907).

The Harkness engine ran therefore for over fifty-seven years and the Powell engine ran for over fifty-three years. These machines rarely gave trouble and were the real "standbys" for over a half century, and were capable of good service at the date of starting pumping from the new works at California (Cincinnati).

A new stone masonry reservoir on the site of the original wooden reservoir was constructed 1850–1853. The two divisions having a combined capacity of 5,500,000 gallons with a water depth of 20.50 feet.

In 1865 Mr. James P. Kirkwood of Brooklyn, New York, then the foremost water works engineer in America, was called to Cincinnati for the purpose of investigating and reporting on the requirements of the city for a new and enlarged water works and the possible adoption of a new source of water supply, many complaints

having been made before that date upon the unsatisfactory condition of the Ohio River water. Mr. Kirkwood began with an inquiry into the past and prospective population growth of the city and from the diagrams which he constructed he reached the conclusion that the population of the city in 1890 (twenty-five years ago) would be larger than it is at the present date. He made the same mistake that many others have made since his time, of assuming that the past will be an exact index of the future. It will be interesting and instructive to reproduce his population table and parallel it with the census reports to 1910.

Cincinnati Population

Year	*Census*	*Kirkwood, 1865, Prediction*	*Hill, 1896, Prediction*
1800	750		
1810	2,540		
1820	9,602		
1830	24,831		
1840	46,338		
1850	115,438		
1860	161,044		
1870	216,239	225,460	
1880	255,139	315,460	
1890	297,000	431,644	
1900	325,902		335,000
1910	364,463		370,000
1915	Estimated 400,000		385,000

In 1896 the Engineer Commission on Extension and Betterment of the City Water Works had occasion to study the probable growth of population in the city, including the growth in territory to be annexed, and the results from the curve then projected are given for the years shown.

By adding the neighboring cities in Kentucky and the suburbs in Hamilton County, Cincinnati has a population at the present time of nearly 550,000.

In projecting the capacity for a new water works Mr. Kirkwood assumed that the statistics of consumption for New York and Brooklyn would apply to Cincinnati, and adopted a per capita rate of 65 gallons, our consumption rate at present is about 130 gallons per capita, or twice Mr. Kirkwood's quantity.

"Mr. Kirkwood made a thorough survey and investigation of the various sources for a new water supply, and adopted a pumping system, continuing the Ohio River as a source. The site selected was about two miles above the present pumping works (1880), and the plan embraced two lifts, with subsiding and filtering reservoirs. The cost was placed at $3,038,214.07."

"The plan was highly recommended by a majority of the water commissioners, but the minority report advocated retaining the pumping works, Front Street Station, and the construction of additional reservoirs. The latter plan was adopted, and the Garden of Eden purchased for reservoir and park purposes on 6th of January, 1866."

None of Mr. Kirkwood's recommendations were adopted, although his report shows a very thorough study of conditions as they existed, even to the necessity for subsidence and filtration of the Ohio River water before it was distributed to consumers. In Mr. Kirkwood's day not much was known of bacterial purification of water and his terms for a pure and wholesome water was that it should be "clear and colorless."

It may be of interest to note that the late Mr. J. J. R. Croess of New York was Mr. Kirkwood's principal assistant on the Cincinnati investigation.

Using plain sand filters and including the cost of settling basins of 84,000,000 gallons capacity, Mr. Kirkwood figures the cost of subsidence and filtration at $18.50 per million gallons, including fixed charges on the construction cost. Omitting fixed charges on the subsiding basins and filters he estimated the operating and maintenance cost at $1.37 per million gallons, or about the cost which he subsequently found abroad upon his visit to Europe, in 1866. Mr. Kirkwood's plans also provided for a storage reservoir of 152,000,000 gallons capacity for the subsided and filtered water.

The reservoir in Eden Park (Garden of Eden) consists of two divisions, one containing 43,000,000 gallons, and the other 57,000,000 gallons. The basin is constructed in a ravine of very steep channel and side slopes. The smaller division is closed at the lower end of the ravine by a massive retaining wall 120 feet high at the middle of the ravine. The division wall between the two compartments of the basin is 67½ feet high at the middle of the ravine. The water depth is 30 feet. The reservoir and walls were designed and in part built by Mr. Henry Earnshaw at that time superintendent of the city water works.

During 1872, or seven years after Mr. Kirkwood's investigation, the trustees of the water works entered into contract with a local company for two additional pumping engines, each of 7,500,000 gallons daily capacity. These engines were designed by Mr. Theodore R. Scowden, and were of the vertical crank and fly wheel direct acting type, with walking beams to connect the steam pistons to the cranks and fly wheels placed below the steam cylinders under the engine room floor.

The design of these engines was modern for non-condensing machines, and among other innovations were furnished with differential plunger pumps of the "Wright" type.

One difficulty always experienced with the Cincinnati pumping engines in the Front Street Station was due to the considerable vertical separation of the steam and water ends. The pumps were set on solid masonry foundations, while the steam cylinders and rotating parts were mounted on iron skeleton frames or towers, 50 or 60 feet high. An exception should be made of the Wetherill engines, which were erected on horizontal steel girders set in heavy masonry side walls. The Scowden engines were started in 1872–1874, and the Wetherill engines in 1885–1886.

Other engines were erected in the Front Street Pumping Station, viz.: the Shield Engine (1865) which was of the Cornish Bull condensing type with a steam cylinder 100 inches diameter by 12 feet stroke. The steam piston, air pump piston and pump piston were all mounted in line on a continuous rod over 55 feet long. The engine and pump never worked very successfully and the machine was so wasteful of fuel that it was never operated from choice. The expected capacity of this machine was 20,000,000 gallons per day, but it rarely worked above a 12,000,000 gallon rate. The engine was so untrustworthy that the attendants were never allowed to leave their respective stations while it was running.

The designer of the engine, Mr. George Shield, was the leading steam engineer of the city when he built this machine, and its failure as a safe, economical and useful unit of the power in the Front Street Station destroyed his reputation and was supposed to have shortened his life. No other engine of the Shield type was ever built either before or since. While it was patterned in part after the Cornish Bull engine and pump, the departures from the original type were sufficient to bring about substantial failure of the machine as a useful adjunct of the Pumping Station.

Two duplex vertical direct acting Worthington pumping engines were also erected in this station (1888), each of a rated capacity of 12,000,000 gallons per day. These engines never were very successful; indeed it was said that at no time in their history were both engines in condition to operate simultaneously, although it is well known that at critical periods everything at the Front Street Station that could lift water from the Ohio River was required in service.

Excepting the 20,000,000 gallons Shield engine, all others built from local designs by local builders were successful, the so-called combination (steamboat) engines, the Harkness and Powell engines, were in constant service for over fifty years, while the Scowden engines, also built in Cincinnati, ran successfully from 1872 until the station was abandoned December, 1907, a period of thirty-five years. The difficulty with the pumping engines designed and built in the East was that the designers failed to grasp the special necessities of pumping engines where the pumps were often submerged for days at a time in from 10 to 50 feet of water; where all sorts of trash would at times collect in the pump wells to interfere with the operation of pumps, and where the steam ends must be as simple and reliable as possible to avoid the stoppage of the power. Engines well adapted to a service where the entire machine could be at all times inspected while in operation, were not adapted to the Ohio River service and the troubles of which there were many within the writer's experience at the Front Street (River) Pumping Station have been experienced in other city water works on the Ohio River. It is thought that the rise and fall of the Ohio River at Cincinnati, 71 feet and $\frac{3}{4}$ inch, is the greatest in the world, and the pumping machinery as heretofore constructed with the connecting rods, links and fly wheels often wading many feet deep in the water presents a condition not paralleled in many other cities of the country, or even out of the country.

"In 1872 the city purchased a site from John Markley, ten miles above the city, for a new water works. The property embraces 146 acres, for which the sum of $22,321.50 was paid."

"Mr. T. R. Scowden submitted plans and estimates for the new works to be located on these grounds, which embraced a pumping system with two lifts, subsiding and distributing reservoirs, and two 42-inch delivery mains, the whole to cost $4,500,000."

Cincinnati is one of the few cities in the world requiring three pumping lifts to get water from the Ohio River to the consumers.

The difference of elevation between low water mark in the river and the highest territory supplied with water within the city limits being 507 feet. There are several states in the Union where the extreme variation of levels within their boundaries is not so great as that which occurs within the corporate limits of this city. Even with the three pumping lifts there are still some premises within the city limits at elevations not reached by the city water.

In 1871, Mr. Theodore R. Scowden was employed to investigate the water supply needs of the city and report upon a new source of supply and comprehensive improvement of the water works. Long previous to this date the people had realized that the water taken from the river at the Front Street Pumping Station was unsatisfactory in quality, and, with frequent breakdowns in the pumping machinery and no considerable storage, was often insufficient in quantity. At that time Eden Park Reservoir had not been constructed, nor had the Scowden engines previously mentioned been installed, so that with only the limited storage in Third Street Reservoir, 5,500,000 gallons, and a total pumping capacity of 14,000,000 gallons for a population of over 220,000, the conditions were on the whole not very promising.

Mr. Scowden before this date had the honor of planning the water works of Cleveland, Louisville and Newport, Kentucky, and was the ranking engineer in Cincinnati in this line of work, and enjoyed a reputation for skill and judgment which was unquestioned by his associates in the profession. But as in the case of Mr. Kirkwood, six years before, his plans and recommendations were set aside, and all that came of his work was the purchase of Markley Farm, and the construction of two new pumping engines previously mentioned. Eden Park Reservoir at that time was under construction, and the sole outcome of Mr. Scowden's very thorough surveys and comprehensive plans was an addition of 15,000,000 gallons to the pumping capacity of the Front Street Station.

Mr. Scowden's plans embraced the location of a source of water supply from the river about ten miles up stream from the Front Street Station, a new pumping station, new modern and ample low and high lift pumping machinery, subsiding reservoirs on the river bank, and a storage basin of 300,000,000 gallons capacity at an elevation sufficient to supply by gravity to Eden Park Reservoir, from which latter when completed, distribution to the city would be made. He also considered the ultimate filtration of the

water and allotted space on the land purchase for the location of filters. The land for the entire works was known as the "Markley Farm purchase," which aside from the rent collected from the farmers through a period of about thirty-six years has been of no benefit to the city. The farm was finally sold upon completion of the new water works improvement, 1907–1908.

During 1885–1886 the Wetherill engines each of 10,000,000 gallons daily capacity were installed in the Front Street Pumping Station, and at later dates as noted 1887–1888 two additional Worthington engines were installed. Meanwhile Eden Park Reservoir was completed and this with the Front Street Station and Third Street Reservoir constituted the primary pumping, subsiding and storage elements of the city water works.

Like the proverbial "poor" mentioned in Scripture, the evils of the source of supply, inadequate and antiquated pumping machinery, old fashion steam boilers, and limited storage of water, were always with us. Apparently since the days of Samuel W. Davies the city had not caught up with the demands and requirements of the people. The press and scientific bodies were constantly pointing to defects and insufficiences in the public water works and demanding a remedy. Laws were enacted by the legislature to provide for a new enlarged and adequate water supply system, votes were taken and through the friction and jealousies of politics, such measures were disapproved at the polls.

During 1895 by the joint investigations of Hon. August Herrmann, afterwards president of the board of commissioners of water works, the writer and one other, it was discovered that an enabling act might be passed by the legislature which would permit the building of a new water works without submitting the matter to a vote of the electors, because it had been shown through a period of nearly seventy years that however much the public was dissatisfied with the existing condition of things it would not by its vote authorize a substantial change. All the additions of pumping engines, reservoirs and pipes since the purchase of the water works in 1839 had been provided for from the revenues of the water works and not by popular bond issues.

After several years of investigation and careful inquiry into the legal status, it was decided in 1895 to proceed upon an investigation, preparation of plans and estimates of costs, and the framing of a law which would permit the city to construct a water works

commensurate with the growth of population and increased demand of the people. Accordingly the city board of administration during December, 1895, appointed a commission of engineers, consisting of the writer, Mr. Samuel Whinery, now of New York, and Mr. George H. Benzenberg of Milwaukee, to conduct an investigation, make surveys, examine water sources and report plans and estimates of cost for the extension and betterment of the city water works. This commission reported March, 1896, upon a general plan for improvement of the water works, which with some necessary changes furnished the foundation upon which the late improvements of the city water works are based.

Cincinnati has today in point of pumping machinery, methods of handling and storing coal, subsidence reservoirs, filtration works, and distribution system, a works not surpassed by any city in or out of the country, and since the members of the Association will have the opportunity of inspecting the details of the work at this Convention, May, 1915, and forming their own opinion of their merits, it is deemed advisable to say no more at this time about them.

In preparing this brief memoir on the history of the Cincinnati Water Works, credit must be given to the late Mr. E. M. Shield, and to the late Mr. Charles Cist, and to Mr. Thomas J. Bell, and others who have formerly written on the subject from which the information herein given has been largely drawn. The development of the Cincinnati Water Works has received the earnest and profound thought and efforts of some of the most distinguished members of the engineering profession, and while some of these have not realized the fruition of their individual ideas, yet each has been an influence in bringing about the ultimate happy result.

WATER ANALYSIS AND THE NITROGEN CONTENT OF WATER

By William M. Booth

All available scientific data, both chemical and bacteriological, should be collected and studied before judgment is passed on a water supply used for food, and such should be systematically recorded by all water works companies.

The nitrogen content of water and the chemical conditions in which this is found have long been considered very valuable, nor is there at present any good reason to discredit the use of such reports.

All sanitarians are familiar with the gradual change of animal and plant nitrogen in the combined form until it reaches the inorganic nitric state, and the chemical changes will not be further discussed than to remark that unpolluted natural waters, with few exceptions, are remarkably free from nitrogen. The analyses[1] are recorded to show how the waters of central New York differ in nitrogen content and in what state this element has been found. All tests have been made according to the methods prescribed by Wanklyn and Mason and are tabulated in parts per million. The total solids determination is the weighed residue from 50 cc. of water, evaporated to dryness on the water bath and placed in a desiccator over sulphuric acid for twelve hours. Chlorine has been determined volumetrically, according to Mason, unless above 50 parts per million, when the gravimetric method was employed. Free and

[1] This paper is a supplement to a paper in the September, 1914, *Journal*, The Use of Nitrate Test in Determining Source of Pollution of a Water Supply, and is intended to correct errors in printing the 1914 paper. The following typographical errors are also noted in the paper in the September *Journal*:

On page 602, first line of second paragraph, read Fig. 2.

Page 602, last line for No. 2 read No. 53.

Page 604, sixth line of first paragraph for No. 4 read No. 55.

Page 606, table heading eighth column read Oxygen consumed and ninth column read Colonies per cc.

Page 609, Nos. 124-126 for New Syracuse read Near Syracuse.

albuminoid ammonia are determined separately, and a check has been made in each instance by estimating the total ammonia in another sample. If this form of nitrogen is known to be unusually high, as in the case of sewage, 10 or 100 cc. are diluted with ammonia free water and are distilled as an original sample, using a proper dilution factor. The nitrates and nitrites are determined according to the Mason method and were made in duplicate using freshly prepared standard solutions. The "oxygen consumed" test is made according to the Mason method. All results shown are the work of the writer unless credited to others. The bacteriological analyses were made by the bacteriologist of the city of Syracuse.

Turning now to the analytical tables (p. 606, vol. 1, no. 3, September, 1914, *Journal*) analyses 1 to 7 inclusive show that rain, snow, ice and distilled water may contain free ammonia, albuminoid ammonia, nitrates and nitrites.

Analyses 22 to 26 inclusive show the absence of nitrites in Syracuse city water beginning at the upper or south end of Skaneateles lake, about 32 miles from the city, and at various points in its progress to the city, with a final analysis in a downtown city block. The water shed has an area of about 74 square miles and nitrites are seldom found in this water. Such sometimes occur in November and during the latter part of March. During the past ten years, the writer has never detected more than 0.002 parts per million. The overflow from the lake becomes the source of power for several mills and contains the sewage from the villages along the stream. The nitrogen in this water is shown in analyses 27 to 30 inclusive. Paper, felts, and woolen cloth are manufactured.

Onondaga creek is a country stream that enters the city of Syracuse at the south end. It is, at present, an open sewer and enters Onondaga lake with a fall through the city of about 40 feet. Analysis 8 was made from a sample taken from the creek as it enters the city, and number 9 shows the nitrogen condition of the water as it enters the lake.

Numbers 9 to 17 inclusive were made at about equal distances through the length of Onondaga Lake, which is five miles long. This lake is the sewage outlet for the city of Syracuse, the town of Solvay and the village of Liverpool. The waters of the lake are naturally very salt. A high nitrite content throughout shows a very unstable condition from a nitrogen standpoint. The Seneca River analysis No. 20 was made at the junction and the large decrease

in salt roughly indicates the degree of dilution, as the river water is not unusually high in chlorine.

Number 21 is the analysis of a sewer water from the city that enters the lake.

At its mouth Onondaga Creek has a nauseating odor and contains suspended solids. At the Seneca River junction, the samples taken were free from odor and contained practically no suspended solids.

Numbers 38 to 40 inclusive are tests of Lake Ontario water, and were made to show the efficiency of the mechanical filtration plant of the Rochester and Lake Ontario Water Company at Charlotte.

Number 42 is the analysis of Hemlock Lake water which is the main supply of the city of Rochester. It is now used in conjunction with the purified water from Lake Ontario. Both sources of supply are considered excellent and the total nitrogen content is low.

Number 41 is an analysis of unfiltered Niagara River water, used in the city of Lockport.

Numbers 80 to 83 show that the supply of the city of Fulton is a composite water. The Great Bear Spring has no connection with the well known water of that name. Just west of Fulton there is a lake, the water of which is used for manufacturing purposes in the city. The outlet is low and sluggish, and analysis 31 shows the condition of the water at this point. After use in manufacturing, the increase in nitrogen is shown in numbers 32 to 37 inclusive. The latter is undiluted factory waste.

The village of Seneca Falls (see map in September, 1914 *Journal*) is supplied by water from Cayuga Lake just above the northern outlet. At this point the lake is shallow; many cottages are located on the western bank, and the village of Cayuga lies opposite. Although 40 miles in length and, at points, several hundred feet in depth, a number of large towns sewer directly into this lake, and nitrites are normally present in samples taken from the outlet, especially after the summer season. To determine the condition of the water at the north end of the lake, analyses 43 to 51 were made. The writer testified that the nitrites found in this water showed pollution too serious to admit of its use in the raw state, while several well known experts declared that the water was entirely potable. However, a mechanical filtration plant has been installed by order of the state Board of Health.

Numbers 92 to 95 inclusive are analyses of new wells, driven

in low ground beside the Clyde River. Employees drank this water for a short time, but were physically inconvenienced and another source was substituted.

Numbers 96 to 100 inclusive are analyses made after seven deaths from typhoid fever, supposed to have been caused by impure water, at a club house in the Adirondacks. The location, on the banks of a river, was formerly ideal, but the waters of the stream were dammed by the state at a point several miles below, and the banks overflowed for miles. The water was made stagnant and trees were killed on both banks. Presumably the sewage contaminated the wells which were driven in sand. A new source was secured on higher ground, a septic tank was built, and no severe sickness from water has occurred since.

The remaining analyses have been taken from miscellaneous records, and are explained in the margin. Numbers 101 and 102 are particularly interesting, as the highest nitrate nitrogen recorded in the list was found at this point. After the barn had been turned into a garage, the well became available as a potable water supply.

Numbers 103, 104, and 105 show how a new well furnishes water of varying quality. This well was pumped continuously from September to December, by means of an air lift.

Number 106 is extraordinarily high in nitrites.

The above analyses show the nitrogen content of some central New York waters, and from them the writer draws the following conclusions:

Many natural waters of this area contain nitrogen in all of the forms reported in the analytical scheme.

Water containing sewage is in a highly unstable condition as regards the form in which nitrogen is found.

Records should be kept showing the nitrogen content of potable waters, and weekly, if possible daily, tests should be made.

No quantitative relationship exists between the nitrogen of water and the bacteriological content.

The presence of nitrites in water ordinarily free from this form of nitrogen must be regarded with suspicion.

If nitrates are present in water above one part per million, it may have an unhealthy source.

A SPECIAL WATER STANDARD

By W. F. Monfort

The adoption by the treasury department of a bacteriological standard for drinking water supplied by common carriers in interstate commerce marks a further advance in public sanitation. The sanitary drinking cup has been in evidence on trains for several years in most states, and measures intended to protect the traveling public against infection have been enforced with various degrees of success. The compression cock still invites carelessness. The irresponsible passenger still drinks from the faucet instead of from "an envelope." The education of the entire traveling public to habitual regard of sanitary precautions is a slow process. The most flagrant offender, the employee, who mixes good or bad water with ice of doubtful origin and worse history, is the real object of attack in the campaign for which this special standard affords a basis. Within the past few months regulations have been made effective forbidding direct icing of water on lake steamers. Thus far no order has been issued as to railroads.

The State Board of Health of Kansas issued an order that after July 1, 1913, ice must not come in contact with drinking water as supplied on trains or provided in railway stations. Many stations in France which possess the requisite supply of electricity are provided with sterilizing apparatus for providing a safe supply. The practice has been growing since 1913. Whatever solution of a difficult problem may be adopted by railway officials in this country, the establishment of a standard of quality is an important step.

The standard adopted was in accordance with the conclusion of a commission of fifteen men prominent in sanitary science appointed in January, 1913, by the surgeon general of the United States, "to recommend standards of purity." It is significant that after almost two years' consideration, they have made a progress report covering "the maximum limits of permissible bacteriological contamination," deferring as more involved the question of limits of permissible impurities other than bacteriological. The Commission evidently

experienced the very serious difficulty, well stated by Mr. George A. Johnson in his paper before the 1913 convention of this Association, of correlating the fitness of a water for drinking purposes with definite numerical data as to turbidity, color and specific dissolved mineral matter. The problem in this instance is complicated by the extremes of mineral and physical characteristics which occur from the soft waters of New England to the alkaline supplies of the southwest.

It would not appear difficult to arrive at permissible limits for lead, copper and iron due to contact with containers. The Commission has probably preferred to withold any conclusions it may have reached with respect to chemical and physical properties until this portion of its report should be presented in entirety.

It is emphatically stated that these limits of impurity are established for drinking water in specific conditions where judgment must be based on laboratory work only, without the possibility of knowledge derivable from a survey of its source or from repeated examinations.

The bacteriological standard recommended for this special class of waters will meet with unreserved approval generally.

1. The agar count at 37°C. for 24 hours shall not exceed 100 per cubic centimeter.

2. Not more than one out of five 10 cc. portions of any sample examined shall show the presence of organisms of the bacillus coli group, which for the purpose of this standard includes all aerobic, acid forming, lactose fermenting organisms.

The routine of examination has been simplified as much as possible, using only plain agar, lactose broth and litmus-lactose-agar or Endo's medium, and embodies the familiar work of several members of the Commission in developing and perfecting discriminations by these simple media. The full text of the report, which may be had as Reprint No. 232 from *Public Health Reports*, is of interest to every member of this Association.

BACTERIOLOGICAL STANDARD FOR DRINKING WATER[1]

The Standard Adopted by the Treasury Department for Drinking Water Supplied to the Public by Common Carriers in Interstate Commerce[2]

The standard is one recommended by a commission appointed for the purpose by the Secretary of the Treasury January 22, 1913. The commission was composed of the following members:

John F. Anderson, Director Hygienic Laboratory, chairman of the commission, Washington, D. C.

Edward Bartow, Director, Illinois Water Survey, Urbana, Ill.

Charles C. Bass, Director, Laboratory of Clinical Medicine, Tulane University, New Orleans, La.

S. J. Crumbine, Secretary State Board of Health, Topeka, Kans.

Edward C. Franklin, Professor of Chemistry, Leland Stanford Junior University, Stanford University, Cal.

Henry Hanson, Bacteriologist, State Board of Health, Jacksonville, Fla.

Charles Gilman Hyde, Professor of Sanitary Engineering, University of California, Berkeley, Cal.

Edwin O. Jordan, Professor of Bacteriology, University of Chicago, Chicago, Ill.

Allan J. McLaughlin, Surgeon, Public Health Service, Washington, D. C.

William H. Park, Director, Research Laboratories, Department of Health, New York City.

Milton J. Rosenau, Professor of Preventive Medicine and Hygiene, Harvard University, Cambridge, Mass.

William T. Sedgwick, Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.

George C. Whipple, Professor of Sanitary Engineering, Harvard University, Cambridge, Mass.

C. E. A. Winslow, Curator, Department of Public Health, American Museum of Natural History, New York City.

Wade H. Frost, Passed Assistant Surgeon, Public Health Service, recorder of the commission, Washington, D. C.

THE BACTERIOLOGICAL STANDARD FOR WATER

The following are the maximum limits of permissible bacteriological impurity:

1. The total number of bacteria developing on standard agar plates, incubated 24 hours at 37 degrees C., shall not exceed 100 per cubic centimeter. Provided, that the estimate shall be made from not less than two plates, showing such numbers and distribution of colonies as to indicate that the estimate is reliable and accurate.

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[1] For the benefit of those members who have not had copies of the Government Document the standard is reproduced here in full.—Editor.

[2] Reprint from the *Public Health Reports*, vol. 29, No. 45, Nov. 6, 1914.

2. Not more than one out of five 10 cc. portions of any sample examined shall show the presence of organisms of the bacillus coli group when tested as follows:

(*a*) Five 10 cc. portions of each sample tested shall be planted, each in a fermentation tube containing not less than 30 cc. of lactose peptone broth. These shall be incubated 48 hours at 37 degrees C. and observed to note gas formation.

(*b*) From each tube showing gas, more than 5 per cent of the closed arm of fermentation tube, plates shall be made after 48 hours' incubation, upon lactose litmus agar or Endo's medium.

(*c*) When plate colonies resembling *B. coli* develop upon either of these plate media within 24 hours, a well-isolated characteristic colony shall be fished and transplanted into a lactose-broth fermentation tube, which shall be incubated at 37 degrees C. for 48 hours.

For the purposes of enforcing any regulations which may be based upon these recommendations the following may be considered sufficient evidence of the presence of organisms of the *Bacillus coli* group.

Formation of gas in fermentation tube containing original sample of water (*a*).

Development of acid-forming colonies on lactose litmus agar plates or bright red colonies on Endo's medium plates, when plates are prepared as directed above under (*b*).

The formation of gas, occupying 10 per cent or more of closed arm of fermentation tube, in lactose peptone broth fermentation tube inoculated with colony fished from 24-hour lactose litmus agar or Endo's medium plate.

These steps are selected with reference to demonstrating the presence on the samples examined of aerobic lactose-fermenting organisms.

3. It is recommended, as a routine procedure, that in addition to five 10 cc. portions, one 1 cc. portion, and one 0.1 cc. portion of each sample examined be planted in a lactose peptone broth fermentation tube, in order to demonstrate more fully the extent of pollution in grossly polluted samples.

4. It is recommended that in the above-designated tests the culture media and methods used shall be in accordance with the specifications of the committee on standard methods of water analysis of the American Public Health Association, as set forth in *Standard Methods of Water Analysis* (A. P. H. A., 1912).

The standard as recommended by the commission was submitted with the following report discussing the question of standards of purity for water in general:

First Progress Report of Commission Appointed to Recommend Standards of Purity for Drinking Water Supplied to the Public by Common Carriers Engaged in Interstate Traffic.

LIMITS OF PERMISSIBLE BACTERIOLOGICAL CONTAMINATION

More than a year has been devoted to consideration and discussion of the problems raised in this connection; but, since the discussion has of neces-

sity been conducted solely through correspondence, progress has inevitably been slow, so that, even after so long a time, there remain a number of questions upon which satisfactory agreement has not yet been reached. Your commission, not wishing, on the one hand, to curtail free discussion of points upon which satisfactory agreement has not been reached, nor, on the other hand, to further delay submitting such recommendations as have been agreed upon, respectfully request that this report, though incomplete, be accepted and utilized pending the rendering of a more complete report dealing with questions not included herein.

As a preface to the recommendations which follow it is desired that a clear distinction be made between "standards of purity" and "limits of permissible impurity." Since purity is an absolute, not a relative, quality, it is obvious that there can be no "standard of purity" other than absolute purity; that this must be the point of departure in estimating deviations from purity or degree of impurity. The recommendations here presented are limits of permissible impurity; they are in no sense "standards of purity." They are recommended not as the nearest approximation to purity which it is desirable to attain; but, on the contrary, as the furthest deviations from purity considered permissible on the water supplies with which this report deals. In this connection it is desired also to emphasize the statement that these limits of impurity are recommended only for application to the special case in question; that is, the control of the sanitary quality of the water supplies of common carriers.

The problem before the commission has been to recommend limits of permissible impurities such as to meet the following requirements:

1. That water supplies conforming to the prescribed requirements shall be free from injurious effects upon the human body and free from offensiveness to the sense of sight, taste, or smell.

2. That supplies of the quality required shall be obtainable by common carriers without prohibitive expense.

3. That the examinations necessary to determine whether a given water supply meets the requirements shall be as few and as simple as consistent with the end in view.

In the attempt to establish limits of this kind it has been inevitable that manifold difficulties should have been encountered. The first of these is the difficulty inherent in any attempt to establish an exact line of demarcation between two such extremes as undoubtedly safe water supplies and those which should assuredly be condemned. This difficulty is enhanced by the necessity of defining uniform limits for waters from such diverse sources and subject to such varied conditions of storage as are the supplies of common carriers, and is still further enhanced by the necessity of limiting to a practicable minimum the number and kind of examinations upon which judgment must be formed. It is a fact so well established as to need no further discussion that the results of bacteriological and chemical examination of a sample of water ought always to be correlated with a knowledge of the source, treatment, and storage of the supply in order to enable a just estimate of the sanitary quality of such supply. With a full appreciation of this fact it is, nevertheless, necessary for our purpose to define limits based solely on the

results of laboratory examinations, since it is often in practice impracticable to obtain first-hand authoritative information regarding the source and handling of the supplies of common carriers as actually distributed to the public. The effect of eliminating a portion of the desirable information is to necessitate somewhat more liberal limits for permissible amounts of impurities which are not actually and definitely injurious and which are removable only at great cost, and narrower limits for permissible inpurities of definitely dangerous character.

In regard to the physical and chemical properties which render water disagreeable to sight, taste, or smell without producing any concrete harmful effect a difficulty is encountered in that the degree of offensiveness is not accurately measurable, being largely dependent upon individual taste and habits. Again, regarding many of the constituents found in natural waters, as, for example, various mineral salts, it is impossible in the present state of our knowledge to definitely specify the ill effects, if any, which given amounts of these substances may produce. Limits upon these impurities must, accordingly, be so placed as to allow the public an ample margin of safety; but to do this raises the question as to how far it is justifiable to tax the carriers to eliminate impurities whose deleterious effects are so doubtful. This question is the more difficult since it is generally impracticable to remove the mineral salts present in waters by measures of practicable application, and consequently narrow limits to the permissible amounts of such substances will have the effect of eliminating many sources of supply—sources which will frequently be the only ones readily available and may yield waters conforming with entire satisfaction to the other more important sanitary requirements. Finally it is in regard to permissible amounts of mineral constituents that the greatest difficulty is encountered in framing such requirements as shall require only simple methods of examination for their enforcement.

It is because of these difficulties and because of the minor sanitary importance of regulating the chemical impurities of water supplies that these questions have been left for further discussion and this report drafted to deal only with the more important question of regulating bacteriological impurities.

The definition of limits for the permissible bacteriological pollution of the water supplies in question is at once more important and simpler than defining limits for permissible chemical impurities. It is more important because the most dangerous of all the impurities which may be present in drinking water are disease-producing bacteria and other parasitic disease germs. It is simpler than the other problems mentioned, because as the result of a vast deal of careful study which has been devoted to the bacteriological quality of water supplies and their effects upon the public health it is now possible to define with reasonable precision what constitutes a bacteriologically safe water supply. Finally, strict regulations, requiring common carriers to provide water of undoubtedly safe bacteriological quality, are thoroughly justified, because where water of the requisite degree of purity is not obtainable from a convenient natural source, it is entirely practicable to obtain a pure supply from a moderately polluted source by comparatively simple and inexpensive processes of purification. The art of water purifi-

cation has, in fact, progressed to the point where there is no longer any excuse whatsoever for using bacteriologically polluted water.

The vast majority of the bacteria found in drinking water supplies are entirely harmless, and regulations designed to insure freedom from disease-producing bacteria must, accordingly, be concerned more with the character than the numbers of the bacteria present. The isolation of the disease-producing bacteria which may be present even in highly polluted waters is so nearly impossible, because of the difficulty of separating them from the much more numerous harmless bacteria with which they are associated, that in actual practice the attempt to directly demonstrate the presence of disease-producing bacteria is seldom made. The bacteriological examination of water supplies has therefore been developed, rather, along the line of determining the number and proportion of certain broad classes of bacteria present in a given volume of water, namely:

1. Bacteria developing distinct colonies within 48 hours at 20 degrees C. on standard gelatin culture medium.

2. Bacteria which developed distinct colonies within 24 hours at 37 degrees C. on standard agar culture medium.

3. Bacteria belonging to the *Bacillus coli* group.

It is beyond the scope of this report to enter into a detailed discussion of the interpretation of results of bacteriological examination of water supplies. In general, reliable interpretations can be made only by those having a sufficiently broad knowledge of bacteriology to enable them to apply the established general principles to each case as it is presented.

The bacteria developing on standard gelatin at 20 degrees C. include a relatively large proportion of harmless bacteria which are normally inhabitants of soils and natural waters free from dangerous pollution. The number of bacteria, as estimated by the standard gelatin count, serves in a general way as an index of the cleanliness of the sample; but to properly interpret the results of such a count it is necessary to have knowledge of the source of the sample examined, the nature of the pollution to which it has been exposed, and the opportunities afforded for multiplication of the harmless varieties of bacteria present. On account of the rapid multiplication of harmless varieties of bacteria, which may take place when water is stored in small containers at moderate temperatures, and the impossibility of making approximately correct allowance for such multiplication, it is believed that the attempt to establish a limit for bacteria developing on gelatin is not practicable for the purposes of the control of supplies of common carriers.

The bacteria developing on standard agar at 37 degrees C. in 24 hours are also chiefly varieties which are entirely harmless. The agar count, however, as compared with the gelatin count, represents a larger proportion of bacteria which find their normal habitat in the animal body and are present in sewage and other discharges from the animal body. Generally speaking, an excessive agar count is sufficient to cause at least a suspicion that the water is polluted with discharges from the animal body, and is therefore unsafe for use as drinking water. Multiplication of the harmless varieties present may, however, take place at ordinary temperatures in water stored in tanks, coolers, bottles, and other containers, thus greatly increasing the agar count,

without, of course, increasing the actual dangerous pollution of the water. This introduces a large source of error into the attempt to interpret the significance of agar counts of samples of waters stored for varying lengths of time under conditions more or less favorable to bacterial multiplication. It is largely for this reason that it has been considered necessary to allow very liberal limits to the agar count of the water supplies of common carriers, and to attach to the results of this method of examination a significance much less than ordinarily attaches to the agar count in examining samples of water freshly removed from known sources.

Bacteria of the *Bacillus coli* group are normally inhabitants of the intestinal tract of warm-blooded animals, and it is believed that under ordinary conditions they do not multiply, in nature, outside of the animal body; that in drinking water supplies they tend, on the contrary, to die out rather rapidly. The presence of such bacteria in water may accordingly be considered valid evidence that the water has been polluted with the intestinal discharges of some of the higher animals and the numbers present may be considered a fair index of the extent of such pollution. Since practically all of the diseases which are known to be commonly transmitted through water supplies are due to germs which are discharged from the intestines of infected persons, pollution with intestinal discharges is not only the most offensive but by far the most dangerous kind of pollution to which water supplies are exposed.

It is obviously desirable that drinking waters should be at all times entirely free from such offensive and dangerous pollution, but it would be both impracticable and unnecessary to enforce a requirement that the supplies of common carriers should always be entirely free from bacteria of the *Bacillus coli* group. The test is an extremely delicate one, showing traces of pollution not detectable by any other means; all surface waters are naturally subject to more or less pollution with animal excreta, and experience has shown that efficient purification, rendering originally polluted waters entirely safe and satisfactory, never extends to the point of constantly and entirely removing all bacteria of the Bacillus coli group.

The limits recommended for permissible pollution of this character are as rigid as it is possible to make them without, on the one hand, requiring absolute freedom from such bacteria or, on the other hand, increasing materially the cumbersomeness of the examinations necessary to ascertain compliance with the requirements. Compliance with the requirements herein recommended will insure a quality of water supplies equal to that of municipal supplies which have been demonstrated by experience to be entirely safe and satisfactory and will at the same time impose no great burden upon common carriers, since it is entirely practicable, with moderate expense and pains, to purify water to the degree required.

In submitting the recommendations herewith presented it may be again emphasized that the limits defined are recommended with reference solely to the special object of the control of the supplies of common carriers, having in mind that these supplies constitute a special case because of the following reasons:

1. The supplies come from widely diversified and mixed sources.

2. Samples taken from common carriers represent waters stored for various lengths of time under varying conditions.

3. In view of the impossibility of accurately ascertaining the source and history of each supply examined reliance must be placed upon results of laboratory examination to a greater extent than is necessary or justified in estimating the quality of a supply from a known source with a known history.

It is requested that the recommendation of these hard-and-fast limits of bacteriological impurity be not interpreted as minimizing in any way the importance of field surveys in estimating the sanitary quality of water supplies in general. It is always desirable to obtain information from as many angles as possible, and this is, indeed, necessary in order to form an altogether fair estimate of an individual supply.

Pending the preparation of the report recommending specific limits for permissible chemical impurities, it is recommended that water supplies which may be bacteriologically sanitary be excluded from use when, in the opinion of the Surgeon General, they are definitely injurious to health or grossly offensive by reason of chemical impurities or physical properties.

EXAMINATION OF DRINKING WATER ON RAILWAY TRAINS

By Edward Bartow, Ph.D.

In order to determine the character of water furnished to the passengers on railway trains, 100 samples from water containers on trains have been collected and analyzed by members of the staff of the Illinois State Water Survey. Although the number of samples examined is small, the information obtained concerning the actual condition of the waters should be valuable in formulating practical standards. The samples were secured from trains at Champaign, Urbana, Kankakee and Chicago. It was thus possible to secure samples from cars coming from all parts of the country: from Boston, New York and other points in the East; Jacksonville, New Orleans and Galveston in the South; San Francisco, Los Angeles and Denver in the West; Minneapolis, Duluth, Sault St. Marie in the North. The water is usually a mixture from several sources. It was impossible to learn the points from which all the water had been taken, but with five exceptions the table indicates the points at which the tanks were last filled.

Of the 101 samples, 28 of the tanks were said to have been last filled at Chicago, 9 at Peoria, 8 at Centralia, 6 at Detroit, 5 at Cincinnati, 4 at Indianapolis, 3 at Kansas City, Missouri; 2 each at Memphis, Tennessee; Salamanca, New York; and New York City; 1 each at Boston, Massachusetts; Buffalo, New York; Champaign, Illinois; Dubuque, Iowa, Effingham, Illinois; Forrest, Illinois; Ft. Madison, Iowa; Ft. Wayne, Indiana; Grand Rapids, Michigan; Havana, Illinois; Lincoln, Nebraska; Mason City, Iowa; Mattoon, Illinois; Minneapolis, Minnesota; Montreal, Province of Quebec; Nashville, Tennessee; Parsons, Kansas; Pittsburgh, Pennsylvania; St. Louis, Missouri; St. Paul, Minnesota; Sioux City, Iowa; South Bend, Indiana; Springfield, Illinois; 4 were bottled water from Hammond, Louisiana, and 1 bottled water from Waukesha, Wisconsin, and unknown 5. The majority of samples, 57, were taken from coaches, 19 from sleepers, 8 from dining cars, 7 from smoking

cars, 6 from parlor cars, 2 from tourist sleepers, and of 3 there was no record.

The analyses include both bacteriological and chemical examinations and an attempt has been made to make them as complete as possible when using 120 cc. samples for bacterial examination and 1 liter samples for the chemical tests.

METHODS OF ANALYSIS

The analyses have been made as far as possible in accordance with Standard Methods of Water Analysis of the American Public Health Association (1912) and all analyses made after May 1 include confirmations of *B. coli*, made in accordance with the recommendations of the Commission on Standards for Common Carriers in Interstate Commerce.

For method of determining *Turbidity*, see Standard Methods, page 55. *Color*, Standard Methods, page 8. *Odor*, Standard Methods, page 8. *Residue*, Standard Methods, page 30; but before weighing the residue was heated in an oven for one hour at 180°. *Chlorine*, Standard Methods, page 42.

Magnesium. Neutralize 100 cc. of the water with $\frac{N}{50}$ sulphuric acid using methyl orange as indicator. Boil to expel carbon dioxide. Add 25 cc. of a saturated solution of lime water. Dilute to exactly 200 cc. with boiled distilled water. Cool and filter through a dry filter paper, rejecting the first 25 cc., titrate 50 cc. with $\frac{N}{50}$ sulphuric acid using methyl orange as indicator. Make a parallel determination using 100 cc. of pure distilled water. The number of cubic centimeters of $\frac{N}{50}$ acid required for the distilled water, minus the number of cubic centimeters of $\frac{N}{50}$ acid required for the sample times 9.6 equals parts per million of magnesium (Mg).

Alkalinity. Titrate 100 cc. of the water in a 200 cc. flask with $\frac{N}{50}$ sulphuric acid using first phenolphthalein and then methyl orange as indicators. The number of cubic centimeters of $\frac{N}{50}$ acid required times 10 equals parts per million of alkalinity in terms of $CaCO_3$.

Hardness. To the 100 cc. neutralized in determining alkalinity, add 10 cc. of soda reagent, a mixture of equal parts of approximately $\frac{N}{10}$ sodium hydroxide and $\frac{N}{10}$ sodium carbonate. Dilute with distilled water to exactly 200 cc. Allow to filter through dry filter paper rejecting the first 25 cc. and titrate 50 cc. of the filtrate with $\frac{N}{50}$ sulphuric acid to the methyl orange endpoint. Make a parallel

TABLE I

Analyses of water taken from railway trains

SAMPLE NO.	DATE OF COLLECTION	COLLECTOR	CITY	RAILROAD	TRAIN NO.	CAR	TANK FILLED AT	TURBIDITY	COLOR	ODOR	RESIDUE	CHLORINE	ALKALINITY	IRON	BACTERIAL COUNT		B. COLI IN LACTOSE BROTH SPECIAL 10 CC.
															Gelatin	Agar	
	1913																
1	Dec. 29	H.*	Champaign	I. C.	2	Diner	Hammond, La.	† 2	0	0	182	3	96	0.3	30,000	8,000	5–
2	Dec. 29	H.	Champaign	I. C.	2	Coach 28	Memphis	0	0	0	19	0	12	0.0	280	14	5–
3	Dec. 29	H.	Champaign	I. C.	2	Coach 3127	Centralia	1	0	0	344	23	92	0.0	187	5	3– 2+
4	Dec. 30	H.	Champaign	I. T. S.		Coach		1	0	0	18	0	10	0.0	125	18	5–
5	Dec. 30	H.	Champaign	Big 4	16	Coach 644	Peoria	3	0	0	80	27	20	0.0		13	3– 2+
6	Dec. 30	H.	Champaign	Wabash	36	Smoker	Champaign	8	20	0	426	0	356	0.6	10,000	1,500	5–
7	Dec. 31	H.	Champaign	I. C.	1	Diner	Hammond, La.	† 2	0	0	191	4	96	0.2	15,000	10,000	1– 4+
8	Dec. 31	H.	Champaign	I. C.	1	Sleeper	Chicago	15	20	0	147	1	94	0.4	1,500	510	2– 3+
9	Dec. 31	H.	Champaign	I. C.	1	Coach 2109	Chicago	10	5	0	159	3	96	0.0	54	23	5–
	1914																
10	Jan. 5	T.	Champaign	I. C.	1	Diner	Hammond, La.	† 2	0	0	205	10	100	0.3	1	4	5–
11	Jan. 5	T.	Champaign	I. C.	1	Coach	Chicago	5	0	0	357	50	76	0.0	600	61	2– 3+
12	Jan. 5	T.	Champaign	I. C.	1	Coach	Chicago	20	5	0	170	3	108	0.1	90	36	2– 3+
13	Jan. 5	T.	Champaign	I. C.	24	Smoker	Centralia	3	0	0	148	32	28	0.0	20	15	4– 1+
14	Jan. 5	T.	Champaign	I. C.	24	Coach	Centralia	0	0	0	42	2	26	0.0	160	75	5–
15	Jan. 5	T.	Champaign	I. C.	24	Coach	Effingham	0	0	0	150	12	84	0.0	61	24	5–
16	Jan. 5	H.	Kankakee	C. I. & S.		Coach	South Bend, Ind.	0	0	0	331	10	216	0.0	140	30	5–
17	Jan. 7	T.	Champaign	Big 4	16	Coach	Peoria	7	3	0	526	22	268	2.5	36	14	5–
18	Jan. 7	T.	Champaign	Big 4	16	Coach	Peoria	7	0	0	524	2	260	0.0	52	19	4– 1+
19	Jan. 12	M.	Chicago	I. C.	18	Buffet	Springfield	5	5	0	43	8	8	2.0	60	13	5–
20	Jan. 12	M.	Chicago	I. C.	18	Sleeper	Parsons, Kan.	0	0	0	29	3	12	0.0	140	200	5–
21	Jan. 12	M.	Chicago	Big 4	31	Parlor car	Cincinnati, O.	5	0	0	25	2	10	0.05	10,000	2,500	5+
22	Jan. 12	M.	Chicago	Big 4	31	Sleeper	Cincinnati, O.	0	0	0	163	6	36	0.0	300	220	5–
23	Jan. 12	M.	Chicago	Big 4	43	Coach	Cincinnati, O.	2	0	0	102	9	24	0.05	50	10	4– 1+
24	Jan. 12	M.	Chicago	Big 4	43	Sleeper	Cincinnati, O.	12	0	0	91	15	36	0.0	400	54	4– 1+
25	Jan. 12	M.	Chicago	Soo	2	Diner	Waukesha, Wis.†								3,500	300	5–

26	Jan. 19	S.	Chicago	C. & E. I.	21	Car 492		3	0	0	161	24	62	0.1	1,100	69	2-	3+
27	Jan. 19	S.	Chicago	Santa Fe	9	Tourist	Chicago								790	40	4-	1+
28	Jan. 19	S.	Chicago	Santa Fe	9	Diner	Chicago	2	0	0	458	16	278	0.2	18	3	5-	
29	Jan. 19	S.	Chicago	Santa Fe	6	Smoker	Ft. Madison	5	0	0	95	4	38	0.0	6,000	46	5-	
30	Jan. 19	S.	Chicago	C. & E. I.	9	Car 432	Chicago	20	5	0	125	4	86	0.2	1,000	130	3-	2+
31	Jan. 19	S.	Chicago	C. & E. I.	6	Car 976	Nashville, T.	0	0	0	85	4	46	0.0	50,000	6	5-	
32	Jan. 19	S.	Chicago	Erie	47	Sleeper	Salamanca, N. Y.	20	5	0	114	4	78	0.6	500	24	4-	1+
33	Jan. 19	S.	Chicago	Erie	47	Car 1037	Salamanca, N. Y.	2	10	0	37	4	14	0.1	23	4	5-	
34	Jan. 19	S.	Chicago	Wabash	50	Car 1082	Forest, Ill.	25	35	0	48	4	16	1.9	5,000	20	5-	
35	Jan. 19	S.	Chicago	Wabash	7	Sleeper	Montreal	20	20	0	123	6	76	0.0	710	100	5-	

* Collections have been made by W. W. Hanford (H), F. W. Tanner (T), F. W. Mohlman (M), and C. H. Spaulding (S).
† Denotes bottled water.

TABLE II

Analyses of water taken from railway trains

SAMPLE NO.	DATE OF COLLECTION	COLLECTOR	CITY	RAILROAD	TRAIN NO.	CAR	TANK FILLED AT	TURBIDITY	COLOR	ODOR	RESIDUE	CHLORINE	MAGNESIUM	ALKALINITY $CaCO_3$ Ph.	ALKALINITY $CaCO_3$ M. O.	HARDNESS $CaCO_3$	SULPHATE	IRON	COPPER AND LEAD	BACTERIAL COUNT Gelatin	BACTERIAL COUNT Agar	B. COLI GAS FORMATION 10 cc. L. B.	B. COLI GAS FORMATION 10 cc. Conf.
	1914																						
36	May 6	M.*	Chicago	M. C.	7	Sleeper	Grand Rapids	10	5	0	170	5	8.6	4.0	72	112	35.0	0.0	0.0	300	200	5—	5—
37	May 6	M.	Chicago	M. C.	7	Sleeper	Detroit	8	10	0	118	7	4.8		54	48	13.6	0.2	0.1	9	10	3— 2+	3— 2+
38	May 6	M.	Chicago	Big 4	31	Sleeper	Cincinnati	2	0	0	28	0	0.0		7	8	0.0	0.4	0.05	850	600	5—	5—
39	May 6	M.	Chicago	I. C.	10	Sleeper	Memphis	5	0	0	113	4	4.8		76	72	4.9	0.0	10.5	700	1000	2— 3+	5—
40	May 6	M.	Chicago	I. C.	12	Sleeper	Sioux City, Ia.	15	5	0	298	6	18.2		188	196	34.7	0.2	0.05	50,000	125	4— 1+	5—
41	May 6	M.	Chicago	Big 4	3	Diner	Buffalo	10	10	0	165	4	3.8		100	88	11.9	0.15	0.0	950	35	1— 4+	1— 4+
42	May 6	M.	Chicago	I. C.	30	Sleeper	St. Paul	0	0	0	31	0	0.0		5	4	0.0	0.1	0.0	10,000	1,800	5—	5—
43	May 6	M.	Chicago	M. C.	13	Sleeper	Detroit	2	3	0	27	0	0.0		10	4	0.0	0.4	0.0	400	200	3— 2+	3— 2+
44	May 6	M.	Chicago	M. C.	13	Tourist	Boston	2	0	0	20	0	0.0		5	8	0.0	0.5	0.0	30	5	5—	5—
45	May 6	M.	Chicago	I. C.	28	Parlor car	Dubuque, Ia.	2	0	0	123	5	9.6		86	76	8.6	0.1	0.0	550	375	5—	5—
46	May 6	T.*	Champaign	I. C.	1	Car 3131	Chicago	5	0	0	44	1	1.9		20	12	0.0	0.05	0.0	850	320	5+	2— 3+
47	May 13	T.	Champaign	I. C.	24	Car 3106	Centralia	2	0	0	31	0	1.0		8	4	0.0	0.0	0.0	20	14	5—	5—
48	May 13	T.	Champaign	I. C.	24	Car 3777	Centralia	2	0	0	48	1	2.9		20	12	3.7	0.0	0.0	35	20	5—	5—
49	May 13	T.	Champaign	I. C.	1	Car 2514	Chicago	3	0	0	32	0	4.8		14	8	0.0	0.05	0.1	1,350	900	1— 4+	1— 4+
50	May 13	T.	Champaign	I. C.	1	Car 3182	Chicago	3	0	0	130	1	5.8		34	32	43.6	0.0	0.0	10	4	3— 2+	3— 2+
51	May 13	T.	Champaign	I. C.	24	Car 2504	Centralia	2	0	0	38	0	1.0		14	12	3.3	0.0	0.0	80	10	5—	5—
52	May 18	T.	Champaign	Big 4	16	Car 655		2	0	0	85	19	0.0		50	32	0.0	0.2	0.0	10,000	3,000	3— 2+	3— 2+
53	May 18	T.	Champaign	Big 4	16	Coach 729		3	0	0	55	3	8.8		16	24	trace	0.0	0.1	27,000	3,000	5—	5—
54	May 18	T.	Champaign	Big 4	16	Smoker 657	Peoria	10	0	0	330	30	21.6		170	244	55.1	0.15	0.2	500	800	5+	5+
55	May 18	T.	Champaign	Big 4	16	Coach 717	Peoria	10	0	0	260	20	15.4		136	176	45.3	0.15	0.0		1,200	5+	1— 4+
56	May 24	T.	Champaign	I. C.	1	Car 3131	Chicago	2	0	0	60	2	6.7		38	28	trace	0.0	0.0	860	500	5—	5—
57	May 24	T.	Champaign	I. C.	23	Car 3102	Chicago													90	25	5—	5—
58	May 24	T.	Champaign	I. C.	1	Car 2901	Chicago	1	0	0	48	2	2.9		20	16	trace	0.0	0.0	850	400	5—	5—
59	May 24	T.	Champaign	I. C.	23	Car 3162	Chicago	1	0	0	118	2	7.7		62	28	21.2	0.0	0.0	75	25	5—	5—
60	May 28	T.	Champaign	I. C.	1	Coach	Chicago	2	0	0	110	12	6.7		36	48	79.4	0.0	0.0	1,200	350	5—	5—
61	May 28	T.	Champaign	I. C.	23	Smoker	Chicago	2	0	0	34	3	2.9		14	12	28.0	0.0	0.0	30	3	5—	5—
62	May 28	T.	Champaign	I. C.	1	Coach	Chicago	2	0	0	570	42	22.1		139	260	256.0	0.1	0.1	4,000	130	4— 1+	4— 1+
63	May 28	T.	Champaign	I. C.	23	Coach	Chicago	2	0	0	163	5	15.4		103	140	49.0	0.15	0.0	20,000	210	4— 1+	4— 1+
64	June 1	T.	Champaign	Big 4	9	Coach 694	Indianapolis, Ind.	20	5	0	502	24	28.8		280	420	130.0	0.5	0.3	600	350	4— 1+	4— 1+
65	June 1	T.	Champaign	Big 4	9	Coach 655	Peoria	2	0	0	253	14	15.4		143	224	68.7	0.25	0.0	6,000	1,800	5—	5—
66	June 1	T.	Champaign	Big 4	9	Coach 944	Indianapolis, Ind.	2	0	0	467	25	25.9		263	424	123.8	0.4	0.1	180	90	1— 4+	1— 4+
67	June 1	T.	Champaign	Big 4	16	Coach 697	Peoria	2	0	0	202	23	15.4		95	128	40.3	0.2	0.0	160	20	5—	5—

	1914																									
68	June 10	T.	Champaign	Big 4	16	Coach 655	Peoria	0	0	0	286	38	11.5	130	120	42.8	0.0	0.0	12,000	8,000		5+		5+
69	June 10	T.	Champaign	Big 4	9	Coach 944	Indianapolis, Ind.	0	20	0	441	21	4.8	248	220	88.4	0.8	0.0	20,000	11,000		5+		5+
70	June 10	T.	Champaign	Big 4	16	Coach 697	Peoria	0	0	0	219	11	3.8	112	104	48.1	0.1	0.0	25,000	15,000	4−	1+	4−	1+
71	June 10	T.	Champaign	Big 4	9	Coach 743	Indianapolis, Ind.	0	5	0	369	20	17.3	234	200	76.5	0.1	0.0	30,000	10,000		5+		5+
72	June 11	T.	Champaign	I. C.	622	Coach 1579	Havana, Ill.	0	3	0	25	3	5.8	10	44	6.2	1.4	0.0	160	40	5−		5−	
73	June 11	T.	Champaign	I. C.	1	Coach 2507	Chicago	0	0	0	173	3	2.9	93	44	13.6	0.1	0.0	1,350	800		5+	1−	4+
74	June 11	T.	Champaign	I. C.	1	Coach 2514	Chicago	0	0	0	127	2	2.9	94	36	8.2	0.0	0.0	1,800	1,000		5+		5+
75	June 19	B.*	Chicago	C. B. & Q.	2	Coach	Lincoln, Ill.	2	0	0	293	18	11.5	162	112	57.2	0.4	0.0	7,000	2,250	3−	2+	3−	2+
76	June 19	B.	Chicago	C. B. & Q.	58	Sleeper	Minneapolis, Minn.	2	0	0	146	3	6.7	45	36	30.9	0.6	0.0	30	3,600	5−		5−	
77	June 19	B.	Chicago	Penn.	15	Coach	Ft. Wayne, Ind.	0	0	0	162	16	2.9	26	56	65.0	0.6	0.0	15	1,350		5+		5+
78	June 19	B.	Chicago	C. & A.	10	Smoker	Kansas City, Mo.	30	15	3m	268	12	4.8	88	104	83.9	0.0	0.0	80,000	30,000		5+		5+
79	June 19	B.	Chicago	C. M. & St. P.	2	Coach	Mason City, Ia.	0	0	0	170	17	10.6	66	92	40.3	0.0	0.0	5,500	1,500	3−	2+	3−	2+
80	June 18	B.†	Chicago	C. & A.	8	Coach	St. Louis	0	0	0	169	2	12.5	116	116	none	0.0	0.0	10,000	180		5+	1+	4−
81	June 19	B.	Chicago	Penn.	25	Sleeper	Pittsburgh	0	0	0	145	4	12.5	116	96	none	0.0	0.0	220	35	3−	2+	5−	
82	June 19	B.	Chicago	C. B. & Q.	56	Sleeper	Kansas City, Mo.	0	0	0	185	7	12.5	64	76	69.1	0.0	0.0	340	450	3−	2+	3−	2+
83	June 19	B.	Chicago	C. M. & St. P.	12	Sleeper	Kansas City, Mo.	5	0	0	142	6	5.8	50	48	42.8	0.0	0.0	900	2,250	3−	2+	3−	2+
84	June 19	B.	Chicago	Penn.		Parlor car	Chicago	10	0	0	158	5	9.6	114	76	20.6	0.0	0.0	10,000	5,400	3−	2+	3−	2+
85	June 25	C.*	Chicago	M. C.	17	Sleeper	Detroit	2	0	0	128	4	10.6	64	48	trace	0.0	0.0	1,350	230	5−		5−	
86	June 25	C.	Chicago	M. C.	17	Sleeper	Detroit	2	0	0	23	10	6.7	18	8	trace	0.0	0.0	2,900	1,260	5−		5−	
87	June 25	C.	Chicago	M. C.	17	Parlor car	Detroit	2	0	0	58	3	10.6	36	32	trace	0.0	0.0	5,000	510	3−	2+	5−	
88	June 25	C.	Chicago	M. C.	13	Coach	Detroit	2	0	0	166	25	18.2	96	48	trace	0.0	0.0	9,000	520	5−		5−	
89	June 25	C.	Chicago	M. C.	13	Sleeper	New York	2	0	0	48	3	5.8	22	8	trace	0.0	0.0	1,560	640	3−	2+	4−	1+
90	June 25	C.	Chicago	M. C.	13	Sleeper	New York	3	20	0	120	5	15.4	58	72	trace	0 0	0.0	220	91	3−	2+	5−	
91	June 25	C.	Chicago	I. C.	24	Parlor car	Mattoon	5	15	0	302	12	33.6	252	144	trace	trace	0.0	8,100	6,600	4−	1+	4−	1+
92	June 25	C.	Chicago	I. C.	24	Coach	Mattoon	1	0	0	44	2	8.6	16	4	trace	0.0	0.0	260	183	5−		5−	
93	Dec. 30	H.*	Champaign	I. C.	23	Smoker	Chicago	2	3	0	24	6	4.8	21	16	0.0	0.1	0.0	10,000	17	5−		5−	
94	Dec. 30	H.	Champaign	I. C.	24	Coach 2166	Centralia	2	0	0	124	5	12.5	95	76	0.0	0.1	0.0	25	2	5−		5−	
95	Dec. 30	T.*	Champaign	I. C.	1	Coach 3107	Chicago	2	0	0	426	35	19.2	124	192	16.7	0.2	0.0	13	33	5−		5−	
96	Dec. 30	H.*	Champaign	I. C.	24	Coach 2127	Centralia	2	2	0	28	6	0.0	21	0	0.0	0.3	0.0	14	4	5−		5−	
97	Dec. 30	T.*	Champaign	I. C.	1	Coach 2507	Chicago	0	0	0	81	8	6.7	35	32	trace	0 5	0.0	3,000	120	4−	1+		5−
98	Dec. 30	T.	Champaign	I. C.	1	Coach 2515	Chicago	0	2	0	132	16	10.5	42	54	4.8	0.1	0.0	1,200	14	5−		5−	
99	Dec. 30	H.*	Champaign	I. C.	1	Diner	Hammond, La.†	0	2	0	179	7	21.1	100	un-det.	0.0	0.3	0.0	250	110		5+		5+
100	Dec. 31	T.*	Champaign	I. C.	1	Coach 2117	Chicago	3	0	0	60	5	4.8	32	un-det.	0.0	0.0	0.0	5	6	5−		5−	
101	Dec. 31	H.*	Champaign	I. C.	1	Parlor car	Chicago	25	0	0	175	6	6.7	114	80	0.0	1.6	0.0	1	10	5−		5−	
102	June 25	C.*	Chicago	I. C.	25	Coach	Chicago	1	0	0	27	3	0.0	6	0	trace	0.0	0.0	580	260	4−	1+	5−	

* Collections were made by F. W. Mohlman (M), F. W. Tanner (T), A. N. Bennett (B), H. P. Corson (C), W. W. Hanford (H).

† Denotes bottled water.

determination using 100 cc. of distilled water. The number of cubic centimeters of $\frac{N}{50}$ acid used for the distilled water less the number of cubic centimeters $\frac{N}{50}$ acid used for the sample times 40 equals the number of parts per million of hardness as $CaCO_3$. When the alkalinity exceeds the hardness, carbonates or bicarbonates of sodium or potassium are indicated.

Iron. Standard Methods, page 45.

Lead and copper. Use 100 cc. of water, add 2 grams pure crystals of ammonium chloride, 2 cc. acetic acid and 2 to 3 drops of 10 per cent sodium sulphide (Na_2S) solution. Compare immediately with standards containing known amounts of lead nitrate. The standards should contain 0.01, 0.02, 0.03 mg. of Pb.

Number of bacteria per cubic centimeter. The total number of bacteria developing on gelatin incubated 48 hours at 20°C. Standard Methods, 1905, page 82. Total number of bacteria developing on standard agar plates incubated for 24 hours at 37°C. See *Public Health Reports*, November 6, 1914, page 2960.

B. coli. See *Public Health Reports*, November 6, 1914, page 2960.

Ninety-nine samples were examined for turbidity. Of these 70 showed a turbidity less than 5 parts per million; 82 less than 10; 89 less than 15; and only 10 showed 15 or more. A turbidity below 10 would not make the water appear unattractive and it would seem not unreasonable to require a standard of 10 or less.

Ninety-nine samples were examined for color. Seventy-nine of the samples had a color less than 5 parts per million; 88 less than 10; 93 less than 20; and only 6 had 20 or more. A color requirement of 20 or less should be easy to meet and it would not be impossible to meet a requirement of 10 or less.

Ninety-nine samples were examined for residue. Of these 28 had a residue less than 50 parts per million; 36 less than 100; 75 less than 200; 84 less than 300; 90 less than 400; 95 less than 500; and only 4 above 500. The very low residues are undoubtedly due to the presence of melted ice in the coolers. The few samples containing more than 500 parts per million would indicate that a standard of 500 or less could easily be made.

Chlorine was determined in 99 samples. Of these 46 had less than 5 parts per million; 66 had less than 10; 75 had less than 15; 82 had less than 20; 90 had less than 25, and only 9 more than 25 parts per million. It should not be difficult to obtain a water containing less than 15 parts of chlorine per million and it should certainly be easy to obtain water containing less than 25 parts per

million. In special cases where it is not possible to obtain waters with low mineral content, exceptions to the rule may be made. The same may be true also of residue, magnesium sulphates, alkalinity and hardness.

Sixty-six were examined for magnesium. Of these 39 contained less than 10 parts per million; 51 less than 15; 60 less than 20, and only 6 more than 20 parts per million. In the large majority of cases, therefore, it should be easy to obtain waters containing less than 20 parts per million of magnesium. If the magnesium were all present as sulphate, 20 parts of magnesium would be equal to 100 parts of magnesium sulphate.

The alkalinity using phenolphthalein and methyl orange as indicators was determined in 99 samples. In only one case was a water found which was alkaline to phenolphthalein. A requirement that the alkalinity to phenolphthalein shall not be greater than one-half the alkalinity to methyl orange would be easy to fulfill and would guard against the use of water over-treated with lime. Forty-three samples contained less than 50 parts of alkalinity to methyl orange, 71 less than 100, 89 less than 200. Only 10 had an alkalinity of over 200, and only one of more than 300. A standard of 300 or less would be very easy to maintain and a standard of 200 or less would not be impossible.

The total hardness was determined on 64 samples. Of these 34 had a total hardness of less than 50; 45 less than 100; 57 less than 200. Only 7 had a hardness of more than 200 and but 2 a hardness of more than 300. A limit of 300 would be very easy to maintain and it should not be difficult to obtain waters containing less than 200.

Sixty-six waters were examined for sulphates. Thirty-six waters contained less than 10 parts per million of SO_4; 42 less than 25; 54 less than 50; 63 less than 100, and only 3 more than 100. It should be apparently very easy to furnish waters having less than 100 parts per million of sulphates.

Ninety-nine samples were examined for iron. Eighty-six of these contained less than 0.5 parts per million of Fe; 94 less than 1.0; and only 5 had more than two parts per million. A standard of less than one part per million would be very easy to maintain and it would not be unreasonable to ask for less than 0.5 parts.

Sixty-six samples were examined for lead and copper. Fifty-six of these showed no trace of either metal; 7 contained 0.1 part per million; 2 contained 0.2, and 1 contained 0.3. It would not seem difficult to maintain a standard of less than 0.3 part per million.

One hundred samples were plated on gelatin and the number of colonies counted at the end of 48 hours. Of these, 29 samples had less than 99; 16 samples from 100 to 499; 16 from 500 to 999; 9 from 1000 to 1999; 9 from 2000 to 9999; and 21 more than 10,000.

One hundred and two samples were plated on agar and incubated at 37.5°C. for 24 hours. Forty samples showed less than 50 bacteria per cubic centimeter; 7 from 50 to 99; 8 from 100 to 199; 14 from 200 to 499; 8 from 500 to 999; 10 from 1000 to 1999; 10 from 2000 to 9999; and 5 had more than 10,000.

While the large number of bacteria may consist for the most part of harmless forms, the results would indicate unsatisfactory conditions, either in the original water taken or in the conditions of storage and delivery.

The Commission on Standards have made no recommendation concerning the use of gelatin but their standard of less than 100 growing on agar would mean that 53 per cent of the waters examined were unsatisfactory.

One hundred and nine positive tests for gas formation were obtained in 67 samples examined after May 1. Ninety-one, or 83 per cent, of these were shown by the confirmatory tests to contain *B. coli*.

Twenty of the 67 waters were shown to be unsatisfactory by both the standard for *B. coli* and agar count of the Commission on Standards of Purity for Common Carriers. Four more did not conform to the *B. coli* standard alone and 24 more did not conform to the agar count standard, making a total of 49 of 67 samples or 73 per cent which did not conform to the standards set by the Commission.

While our methods differ from Creel (*Hygienic Laboratory Bulletin 100*, 43–57) the results judged by the *B. coli* standard are similar, showing that a better water is found on sleeping cars and parlor cars and the poorer water is found on coaches and smoking cars.

Mr. W. W. Hanford of the Illinois State Water Survey is making a study of the character of the water supplied to railway trains from points in Illinois. As time permits we expect to make more analyses of samples of water taken from trains. An improvement is to be expected as the railway officials are endeavoring to improve conditions as rapidly as possible.

Credit must be given to the members of the laboratory staff of the Illinois State Water Survey for the work which is described in this article.

WATER SUPPLY TREATMENT AT COUNCIL GROVE, KANSAS

By Louis L. Tribus

Among the first essentials in the practical training of engineers is to learn not to despise the day of small things, and to watch and note every strange phenomenon that catches the eye or ear. Countless small scale experiments in the laboratory have resulted in great accomplishments; small models usually exhibit in action the principles that govern full sized productions. More thought and skill are often required to secure efficiency and economy in the design and construction of the small public utility plant than for the much larger ones. Unnecessary first cost and a small annual waste in the one may be a much more serious burden than would be much greater freedom of original expenditure and a larger percentage of annual waste in the other. The writer therefore has no apology to make in presenting for record, and perchance for bringing out some helpful discussion, the following notes about a small water works plant at Council Grove, Kansas.

The real westerner is so accustomed to seeing big mountains, big plains and big rivers, that he naturally uses the big titles even though the object may be really small of its class. Council Grove therefore is a "city," though possessing less than 3000 inhabitants, but it has all the characteristics and aspirations of much larger confrères (Fig. 1). The Neosho River, which bisects it, has but 241 square miles of tributary watershed above Council Grove, yet exhibits many of the unfortunate water supply qualities of its friends and neighbors, the Missouri and Arkansas, which latter ultimately engulfs it, with some additional uncomfortable qualities thrown in.

The vicinity of Council Grove is typical "plains" region; rolling land with about 100 feet differences in elevation; some sharp ridges and many abrupt gulches; white limestone the abundant underlying and outcropping rock. The rock strata are not largely water bearing; gravel and sand deposits are scanty and so permeated with clay as to be of but small service for water storage. Such water as finds its way into the rock seams gradually works out into

the river bottom as small springs, but not large enough or close enough together to repay collection.

The overlying soil is typical Kansas rich black loam and soluble clays. While trees and thick undergrowth are found bordering the river, there is nothing to hold back even ordinary rainfalls, so that the Neosho is very flashy by nature and receives from every storm overloads of sedimentary and partly soluble matters, the latter, present in colloidal form, very difficult of removal. During the middle winter, between storm periods, with consequently low level stage, the river water is clear and fairly potable, but very

FIG. 1. MAIN STREET, COUNCIL GROVE, KANSAS

hard. As the floods come, the latter condition improves, but the silt and colloids make a compound to be shunned, if possible, as a public water supply, but at Council Grove it was "Hobson's Choice."

About 1886, franchise construction operators built a plant, without any treatment of the water, other than such settling as might take place in the receiving well, mains and standpipe. For ten years it served, however, to put out fires and fertilize the lawns. A few inhabitants whose house roofs could not yield sufficient rain water did use the supply, however, with the aid of faucet filters.

In 1897 the writer was called in consultation, but the company could not afford largely in the way of reconstructive expense; a dam was built across the river, raising the level about five feet, impounding 12,000,000 or 15,000,000 gallons or so, giving some settling effect (Fig. 2), and a pressure filter of "New York" type was installed, of rated capacity, 250,000 gallons per day. For a time these facilities served fairly well to meet ordinary consumption. Trouble came, however, in a few years, with the greatly increased use by the railroad shops and yards; the filter was unable

FIG. 2. MISSION DAM AT LOW WATER, SHOWING STEPPING STONES ON TOP OF CORE WALL. PAVED ROADWAY UPSTREAM FROM FOOTWAY

to work rapidly enough, so that the mains became filled with scantily treated liquid, virtually nullifying the excellent filter action at ordinary rates of use.

As the end of the twenty-five years franchise period approached, it was financially unwise to invest further moneys for an enlarged plant, particularly as negotiations were under way for the purchase by the city. The negotiations failed and litigation ensued, but finally adjustment of difficulties was secured by joint effort

of law and engineering, and the writer's firm was authorized to design and carry out the necessary changes, which have been recently completed.

What time may demonstrate as continuing success under all conditions is unknown, but in the few months of operation, dealing some of the time with liquid mud, an effluent of zero turbidity has been delivered, while also meeting continuously the following test conditions.

> The test required for the filtered water shall be a reduction of bacterial content of at least 98 per cent from the content in the raw water, except that when the total number of bacteria is less than 3500 per cubic centimeter in the raw water, the filtrate must not contain in excess of 75 per cubic centimeter.
>
> The filtrate also must be without color, odor or turbidity, or free or decomposed alum, or aluminum hydrate.

During the past twenty-five or so years, the problems of water treatment have received great attention; those of Europe and the eastern United States have yielded under different methods and care practically perfect results as to potability and softness, but the western colloidal waters are still continuously under experiment with only partial success.

The writer does not consider the Council Grove plant ideal in design, for it had to be built to supplement existing works, but it makes possible the handling of the peculiar type of water available, with some degree of scientific care and with practical success.

Briefly described, the water flows through a pipe inlet into a deep 30-foot diameter river-side stone well, from which a 600,000-gallons per 24 hours centrifugal pump lifts it, a combined suction and discharge of 28 feet at low water, to sedimentation basin No. 1, or by cutout to the gravity filters direct. The overflow level of the basins is 3 feet above the sand in the filters. From basin No. 1, which it enters at one end near the bottom, the water flows nearly to the farther end through a low level submerged port connecting with basin No. 2, similarly flowing into No. 3 through a higher level port, and into No. 4 through an opening 18 inches below the upper surface of the water. From No. 4, at similar high level, though still submerged, the water passes to the two 250,000 gallons gravity, rake-agitated and clean-water-back-washed Jewell filters. In each basin, flow is also somewhat checked by cross baffles (Plates I, II III).

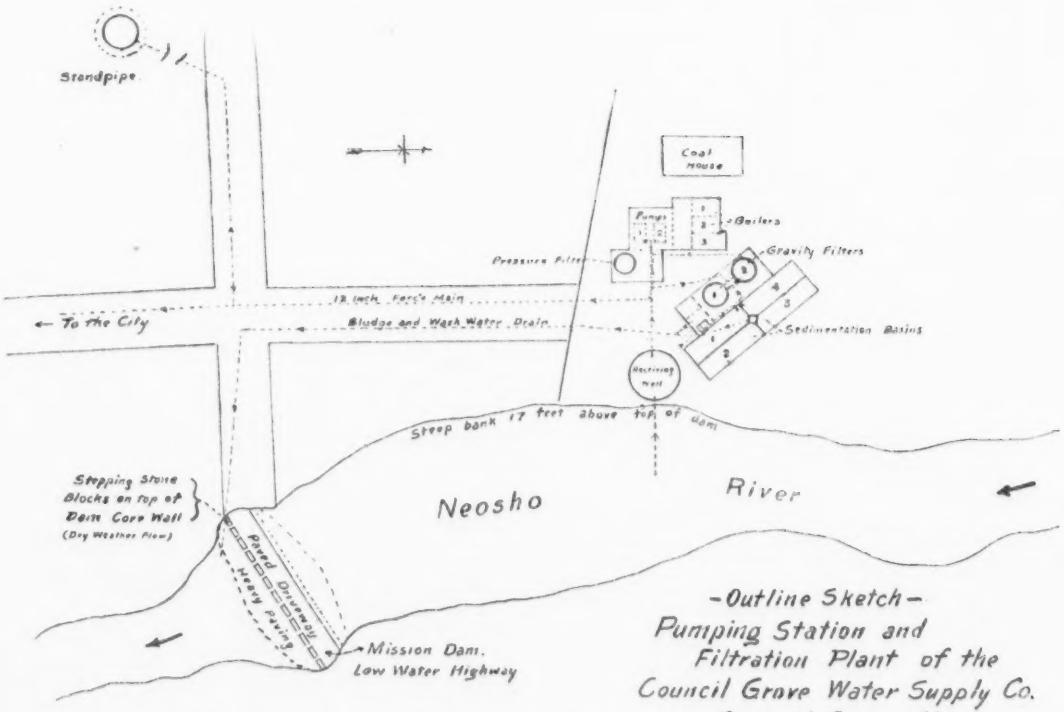
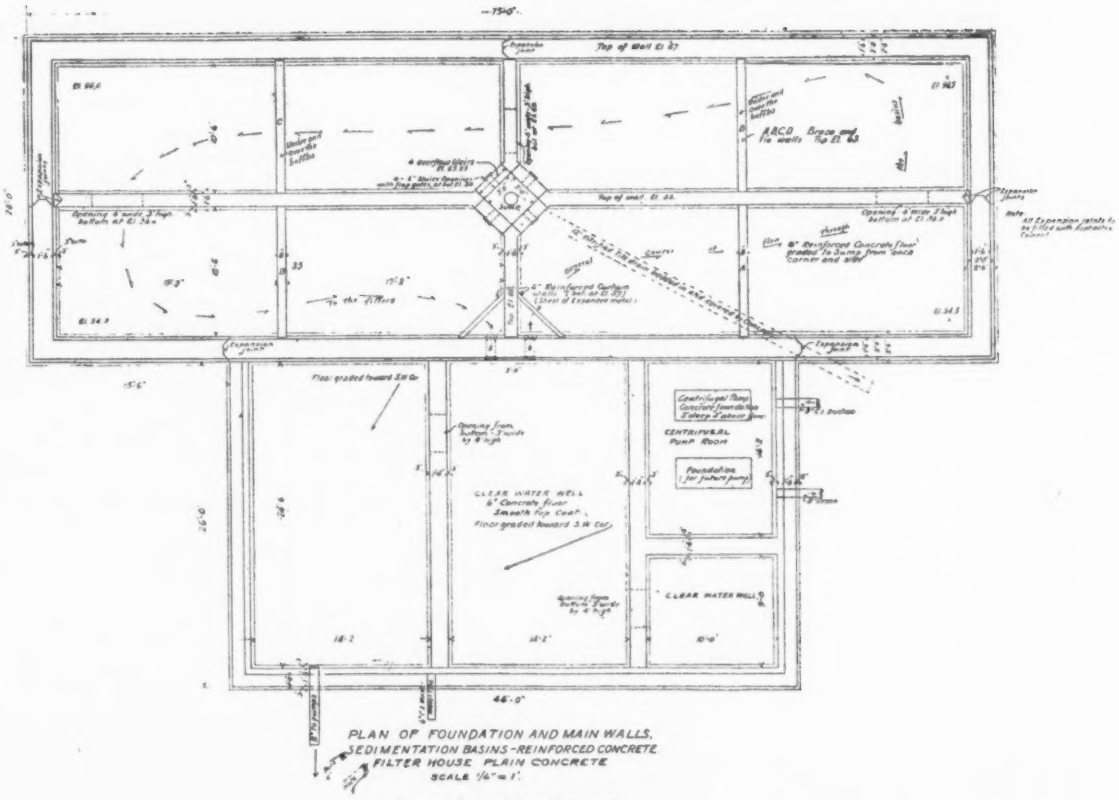

Standpipe
Coal House
Pumps
Boilers
Gravity Filters
Pressure Filter
12 inch Force Main
To the City
Sludge and Wash Water Drain
Sedimentation Basins
Reclaiming Well
Steep bank 17 feet above top of dam
Stepping Stone Blocks on top of Dam Core Wall
(Dry Weather Flow)
Neosho River
Paved Driveway
Heavy Paving
Mission Dam.
Low Water Highway
-Outline Sketch-
Pumping Station and
Filtration Plant of the
Council Grove Water Supply Co.
Council Grove, Kan.

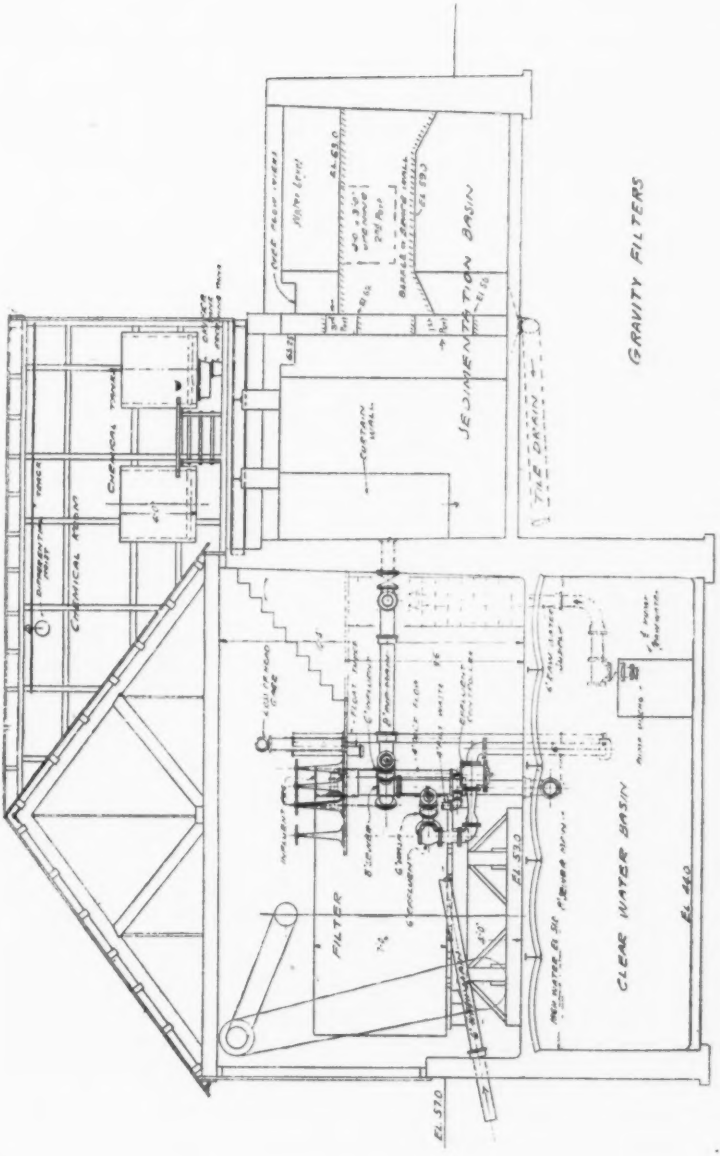
PLATE I


Top of Wall El 87
Expansion Joint
Top of conc. El 86
Opening 4' wide 3' high bottom at El 74.5
Opening 4' wide 3' high bottom at El 74.5
6" Reinforced Concrete floor graded to Sump from each corner and side
4" Reinforced Conc. walls (2 feet at El 85) (Sheet of Expanded metal)
Floor graded toward S.W. Cor.
Opening from bottom 3' wide by 4' high
CENTRIFUGAL PUMP ROOM
Centrifugal Pump Capacity from de Nos 2 when 2 at once flow
Foundation for future pump
CLEAR WATER WELL
6" Concrete floor
Smooth Top Coat
Floor graded toward S.W. Cor.
CLEAR WATER WELL
Opening from bottom 3' wide by 4' high
Expansion Joints
All Expansion joints to be filled with Bituthix Cement
44'-0"

PLAN OF FOUNDATION AND MAIN WALLS.
SEDIMENTATION BASINS - REINFORCED CONCRETE
FILTER HOUSE PLAIN CONCRETE
SCALE 1/4" = 1'.

COUNCIL GROVE WATER SUPPLY CO.

PLATE II



ELEVATION
SCALE 1/8" = 1'

PLATE III

The coagulant is mixed in carefully proportioned quantities and fed through automatic orifice boxes and sight feeds, as experiments show to be best under the differing conditions, at either all possible points, or in any combination or singly (Fig. 3).

1st. At the pump suction; 2d. Inlet to basin No. 1; 3d. At port between basins 2 and 3; 4th. In influent pipe to filters.

From the gravity filters the water passes down to a clear water well in the basement which stores about 40,000 gallons; from this the main water works pumps draw it without lift, delivering into the city system; excess over demand being stored in the standpipe for night use. At the suction inlet there can be given a regulated dose of hypochlorite, if the bacterial condition should seem to require (Fig. 4).

If the new plant should be overburdened at any time and fail to give perfect water, the pumps can drive it in final treatment through the old pressure filter. Tried out as a test this worked effectively. The sedimentation basins (Fig. 5) hold about 125,000 gallons in their 11 feet of depth and can be cleaned out into a sewer which opens from a central overflow and drainage sump, through shear valves, operated from the top of the sump. If all the coagulant was added at one point, either at the inlet, or outlet from the basins, the settled mud in them would be some criterion of action, but as a different condition usually prevails, the regularity of deposit and turbidity is interfered with.

Following the first month of operation, a heavy silt period, the basins were cleaned showing average depths of mud as follows: No. 1, 29 inches; No. 2, 24 inches; No. 3, 16 inches; No. 4, 13½ inches; and frequent washings of the filters were necessary, say four or five times per day. The next month, with better water conditions, indicated mud depths as follows: No. 1, 12 inches; No. 2, 6 inches; No. 3, 5 inches; No. 4, 5½ inches; and much less frequent filter washings, say twice a day, while in January, turbidity was almost nil and filter washings sufficed at twice a week.

During the test days in October, 1914, samples of water were taken at various depths and locations, thoroughly crossectioning the basins, and turbidity readings were compared, indicating the effect of coagulation and subsidence. Even though the water had very slow movement the effect was shown quite handsomely; the minimum turbidity appearing to be between 2 and 4 feet below the surface (Plate IV). At time of these tests, however, the port

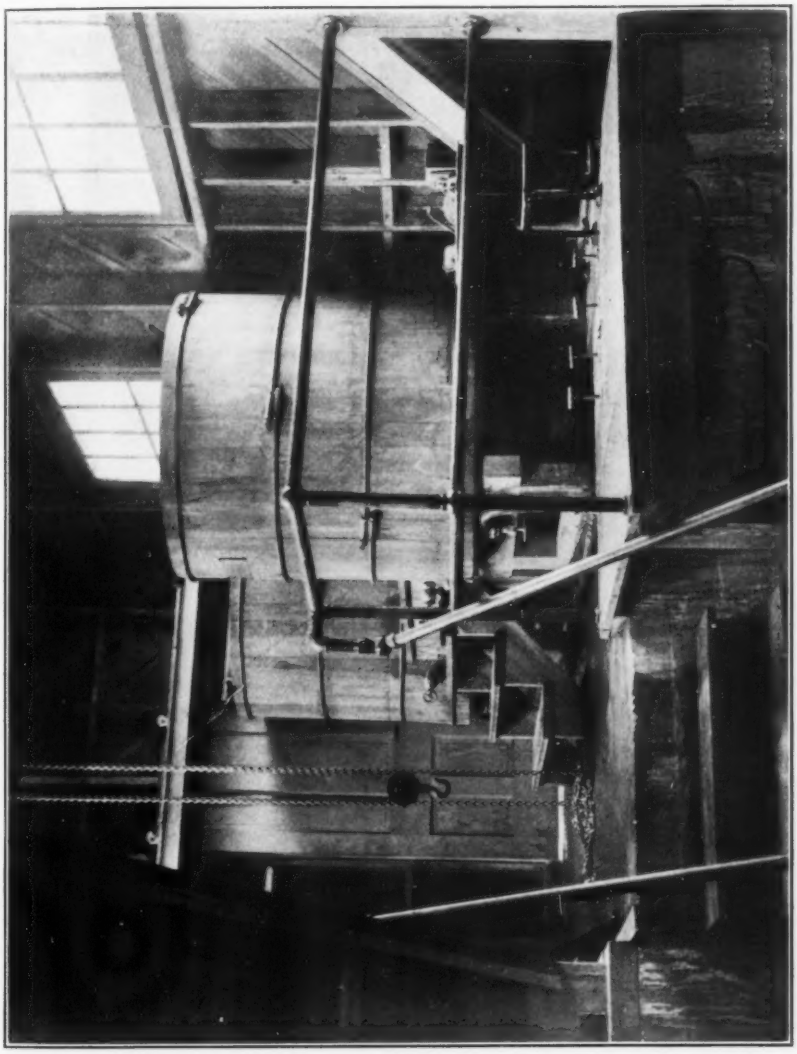


FIG. 3. ALUM TANK AND DOSING APPARATUS BEFORE ADDITION OF SECOND ORIFICE BOX

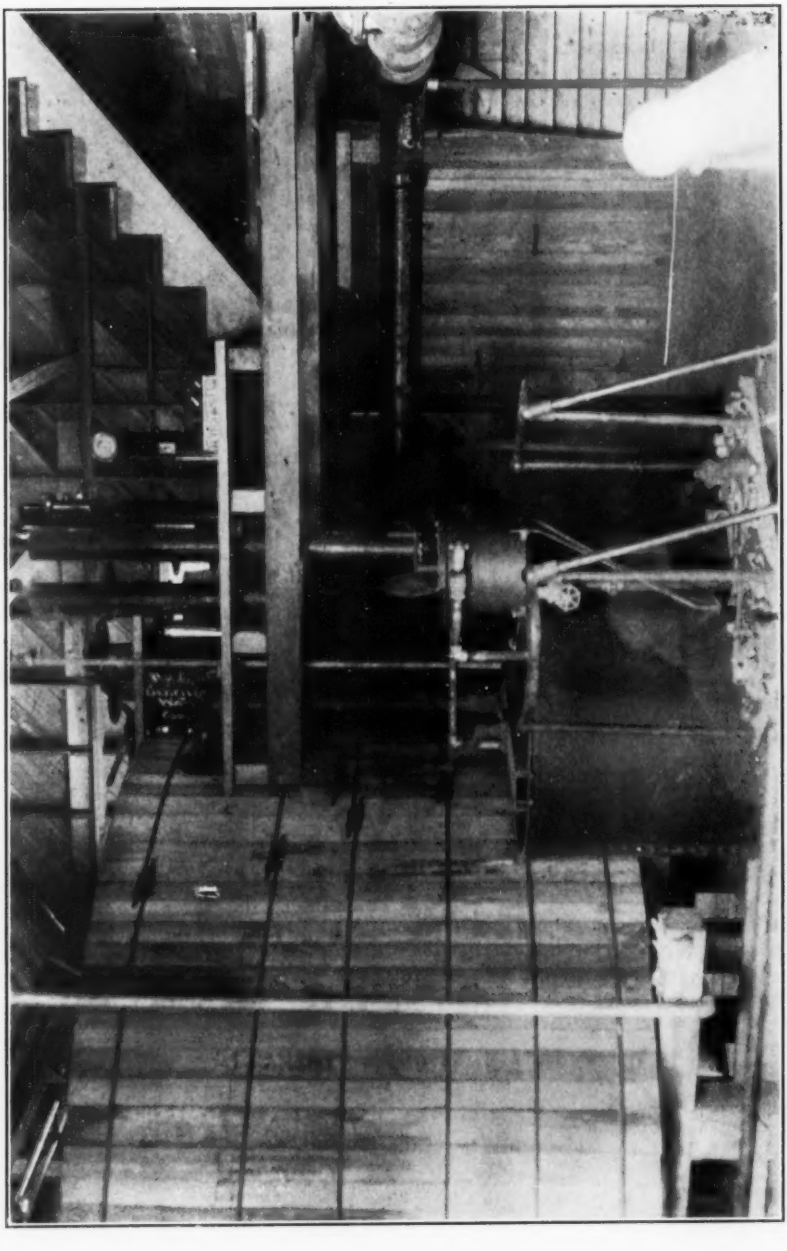


FIG. 4. FILTER NO. 1, HYPOCHLORITE TANK, OPERATING PLATFORM

between basins 3 and 4 was near the bottom of the division wall, while since then as described hereinbefore, it was moved to a higher elevation; this will undoubtedly cause some change to be noted in future tests. The use of coagulant, of course, can not be fully standardized before months or even years shall have elapsed, but the point of prime importance is that the plant purifies the raw water. During test days and for some weeks thereafter alum was used in doses as high as 14 and even up to 20 grains per gallon, flood

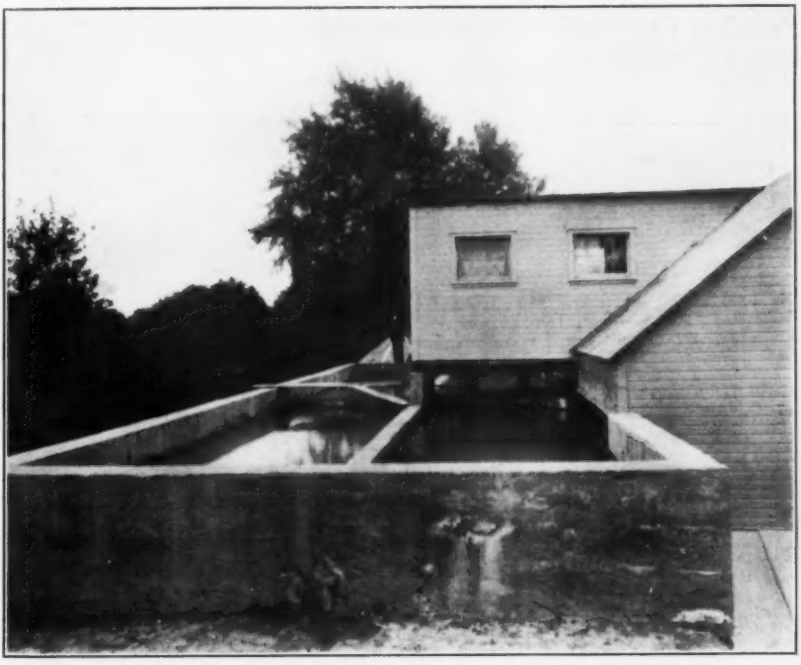


FIG. 5. SEDIMENTATION TANKS AND COAGULATION ROOM

conditions prevailing (Fig. 6), but was soon cut, as experience found to be practicable, to from 4 to 6 grains and now in the winter operation, less than one-half grain is quite sufficient to throw down even the colloids and provide a fine "floc" on the filters for bacterial entanglement. A bright, clear, even sparkling, palatable healthful water is now furnished continuously, where it took mighty faith to even hope for more than comparative clarification from the new plant when it was first planned. (Figs. 7 and 8).

The Kansas laws give a very large measure of authority over water works and sewerage systems and the state Board of Health is very efficient in living up to its duties. After conference, that board accepted the responsibility through its division of water, of conducting the acceptance test of the improved plant, so such acceptance was made a condition in the company's contracts for construction. Mr. C. A. Haskins, engineer of the division of water, and the writer conferred as to many of the matters at interest, and Mr. F. R. Hesser, assistant engineer, was finally assigned to conduct the agreed upon tests.

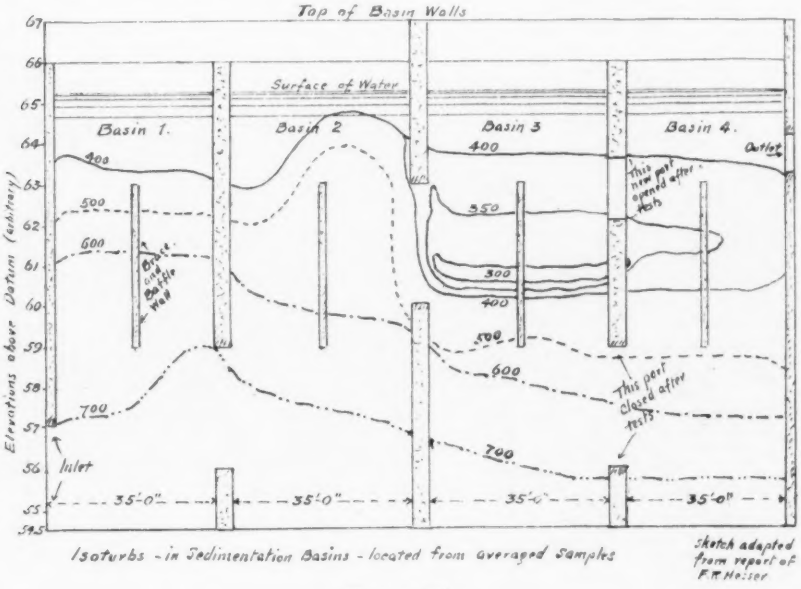


PLATE IV

From Mr. Hesser's report December, 1914, the following extracts will be of interest; summing up, as they do very nicely, the mechanical, chemical and bacteriological action of the plant.

On the night of October 9, a very heavy rain fell in the Neosho Valley above Council Grove and about three feet of water was running over the dam on October 10. The turbidity of the raw water was raised to 1500–1800 parts per million. A portion of this turbidity was so finely divided that a third passage through filter paper failed to remove it. The alkalinity of the raw water was reduced to 50 p.p.m., but the effect of the high turbidity upon the

effectiveness of alum was such that even when 20 grains of alum per gallon of water were being applied, the filtered water had a residual alkalinity of 8.5 p.p.m.

Alum was applied to the raw water at two points in the basins: at the inlet and at the port between basins 2 and 3, while a final dose was applied in the filter influent pipe. The total dose at 12 30 p.m. amounted to 20 grains per gallon. This all passes through one orifice box and it was impossible to determine with any accuracy the amount of the several doses.[1] The lead solution feed pipes were cut and the lower edge spread so that the flow in each could be estimated by eye or actually measured. In this manner, it was estimated that both points in the basin were receiving about 8 grains each, while the influent dose was about 4 grains.

FIG. 6. NEOSHO RIVER. THIRTY-INCH FLOOD PASSING OVER MISSION DAM. SEVENTEEN YEARS OF FLOODS UP TO SIXTEEN FEET IN DEPTH HAVE PASSED OVER THIS DAM WITHOUT CAUSING MATERIAL INJURY

A very finely divided floc was at times noticeable at points in the basin but did not seem to effect a noticeable sedimentation. That complete reaction was prevented seems clear from the fact that the settled water in basin 4 had a residual alkalinity of 35 p.p.m. The turbidity of this water which passed on to the filters was about 950 and the dose of approximately 4 grains of alum per gallon produced no visible or effectual floc, the finely divided turbidity passed completely through the filter, resulting in a final turbidity of 500 p.p.m. and an alkalinity of 20 p.p.m. At 3.30 p.m., however, a slight,

[1] After the tests a second orifice box was installed. L.L.T.

pin floc appeared on the filters and this rapidly increased to heavy flakes, which settled rapidly. The filter effluent at once became clearer until at 5 p.m. the turbidity of filtered water was approximately 10 p.p.m. This production of floc was accompanied by a rapid reduction of alkalinity, the filter effluent at 5 p.m. having 8.5 p.p.m. of alkalinity.

The total alum dose was now reduced to 14 grains per gallon and filtration proceeded satisfactorily until the day's run was closed at 6.30 p.m.

Tables I and II show the results of determinations made during the day, with the exception of special determinations shown by tables entitled, "Turbidity Readings."

TABLE I

		ALKALINITY	TURBIDITY
Raw water at 10.30 a.m.	Oct. 10, 1914	50	1500
Settled water, basin 4	10 30 a.m.	63	—
Settled water, basin 4	11.15 a.m.	44	750
Filtered water	11.15 a.m.	46	600
Settled water, basin 4	12.30 p.m.	35	950
Filtered water	12.30 p.m.	20	500
Filtered water	3.30 p.m.	18	50
Filtered water	3.45 p.m.	14	50
Filtered water	5.00 p.m.	8.5	10

TABLE II

(Extracts from Table I)

Date: Oct. 10, 1914.

Time: See Table.

Alum dose: About 8 grains at inlet; 8 grains between basins 2 and 3; 4 grains on filters.

SAMPLE	TIME	TURBIDITY
Raw water	10 30 a.m.	1500
Basin No. 4	11.15 a.m.	750
Filtered water	11.15 a.m.	600
Basin No. 4	12 30 a.m.	950
Filtered	12.30 a.m.	500

Tables III and IV show the results of some special determinations made at this time. Samples taken from the river and from the outlet ends of the four compartments, with the results, are shown in Table III. It is evident that the heavier suspended matter has remained near the bottom of compartment 1, but is gradually brought nearer the surface as the water flowed through the basins.

In order to learn, if possible, the path of maximum turbidity through the basin and the effect of the tie walls and ports upon the path, I decided to take

samples at various depths in several planes across each compartment, determine the turbidity of each and thus be enabled to plot the lines of equal turbidity both in plan and elevation, from inlet to outlet. Samples were to be taken at depths of 1 foot, 5 feet and 10 feet or at intermediate points where sharp differences in turbidity were noted. To collect the samples, an 8 ounce drug bottle was securely fastened to the end of a 12-foot pole and a cork was attached to a string, by which it could be removed from the bottle when the bottle had been submerged to the proper depth. A Jackson Turbidimeter tube was used with an electric battery and 1 candle power bulb, in place of the standard candle. Before determining the turbidity of individual samples, an average sample was taken from each compartment as follows: An 8-ounce sample was taken at each sampling point at depths of 1 foot, 4½ feet and 8½ feet. Equal volumes of each of the 27 samples thus taken in each compartment were combined to form an average sample of that compartment.

Table IV shows the results obtained. It will be noted that the average turbidity in basin 2 is higher than in 1; that basin 3 shows a reduction of 45 per cent from No. 2 and 35 per cent from No. 1; while No. 4 has an average turbidity higher than that of the first compartment.

The examination of individual samples was taken up about 3 p.m. October 10, but had to be discontinued before the first compartment was completed, because of the burning out of the bulbs used in the flash light. A candle turbidimeter was not at hand and the work could not be completed. On October 12, however, Mr. Tribus took samples at the previously described points from depths of 2 feet, 4 feet, 6 feet and 8 feet. The three samples for each depth on each horizontal line across the compartment were mixed and the resultant turbidity determined approximately by comparison with that of bottled samples previously examined with the turbidimeter. These results are shown in Table V.

Plate IV is a group of curves showing the variation in turbidity along each level, in a diagram of the basins developed along the line of flow, and the probable lines of equal turbidity as determined by the limited data of Table V. This merely illustrates the possibilities of this method of studying basins where sufficient data are obtained.

It was obvious that the basin as arranged was not efficient. The mud evidently settled to the floor, but the depth of the ports between compartments 1 and 2 and 3 made it possible for the most turbid water to be carried through the ports, impinge on the opposite wall and rise in a boil near the center of the basin. These boils were, in fact, visible in basins 2 and 4. It was, therefore, thought best to close the port between No. 3 and No. 4 and cut a new one 4 feet wide by 1.5 feet high, with its bottom 8.5 feet above the basin floor. This change had been made at the time of the last visit but the low turbidity of the raw water made it impossible to determine what its effect may be.

The basins are designed to give a 6-hour retention period on the basis of 500,000 gallons filtered per 24 hours. The actual period is probably approximately 4.5 to 5 hours.

TURBIDITY READINGS

TABLE III

Date: Oct. 10, 1914.
Time: 12.30 p.m.
Raw water: Turbidity 1500.
Alum dose: 8 grains at inlet, 8 grains between basins 2 and 3; 4 grains on filters.

Sample	*Turbidity*
Basin No. 1. Outlet end, 1 foot depth	340 p.p.m.
Basin No. 2. Outlet end, 1 foot depth	675 p.p.m.
Basin No. 3. Outlet end, 1 foot depth	925 p.p.m.
Basin No. 4. Outlet end, 1 foot depth	1000 p.p.m.
Water on Filters	900 p.p.m.
Filter Effluent	500 p.p.m.

TABLE IV

Date: Oct. 10, 1914.
Time: 3 p.m.–4 p.m.
Raw water: Turbidity—1500.
Alum Dose: Same as above.

Sample	*Turbidity*
Basin No. 1. Average Sample	650 p.p.m.
Basin No. 2. Average Sample	750 p.p.m.
Basin No. 3. Average Sample	420 p.p.m.
Basin No. 4. Average Sample	700 p.p.m.

TABLE V

Date: Oct. 12, 1914.
Results reported by Mr. Tribus.
Raw Water Turbidity:—750.

BASIN	SAMPLE	DEPTH OF SAMPLE			
		2 feet	4 feet	6 feet	8 feet
1	1 (a)	520	600	615	
	1 (b)	410	610	615	700
	1 (c)	400	600	700	
2	2 (a)	340	580	625	
	2 (b)	510	535	615	700
	2 (c)	480	550	625	
3	3 (a)	375	330	515	
	3 (b)	375	325	500	650
	3 (c)	375	325	535	
4	4 (a)	390	350	525	
	4 (b)	390	350	525	600
	4 (c)	400	400	550	

RESULTS AND RECOMMENDATIONS

CHEMICAL DOSING AND ACTION

Determinations made November 16, 17 and 18 show a practically normal alkalinity reduction per grain of alum. The dosage was as follows: During the morning of November 16, 2.6 grains of alum per gallon introduced at the inlet to basin No. 1, and 2.3 grains in the influent pipe. Not much floc on basin No. 1 but good in the following basins. Very heavy floc on the filters. At noon, the influent dose was reduced to 1.1 grains per gallon and the raw water dose applied to the pump suction instead of inlet well. A good floc soon appeared in basins, due probably to better mixing in the pump, and carried completely around them. At 10.15 a.m. the pump suction dose had been reduced to 1.6 grains per gallon and a fair floc continued to appear in basin No. 4. With the low turbidity existing at this time, clarification in the basins is not the object sought by coagulation, but the formation of a schumtzdecke on the filters.

It seems probable that by applying a dose of about 1 to 2 grains per gallon between basins 2 and 3, the influent dose might be dispensed with, except for perhaps two hours after starting a new run. At 7.30 a.m., November 18, the raw water dose of 1.6 grains was changed to the port between basins 2 and 3, and 1 grain per gallon was applied to the influent pipe for two hours and then cut out. Samples taken at 10.30 and 11.00 a.m. showed very satisfactory bacterial counts, but can hardly be taken as strictly representative samples, since only 3 hours had elapsed since making the change.

The results of alkalinity and turbidity determinations and bacterial plates made during the test run of November 16, 17 and 18 are reviewed as follows. The filters had been washed at 5.30 p.m. November 15 and allowed to stand idle over night. The sand beds were agitated slightly by the rakes the following morning and the run started at 7.30 a.m.

The first samples were taken from the controller petcocks at 9.15 a.m. and at frequent intervals thereafter. Filter No. 1 was washed thoroughly at 9.25 a.m. and was then operated continuously, except for washing periods until 11.15 a.m. November 17, and the bacterial counts in samples taken from No. 1 during its run are very satisfactory, the maximum being 75 per cc. and the minimum 12 per cc. The samples taken from the power house tap and from No. 2 are not so good, but it must be remembered that No. 2 filter was being subjected to drop tests during the time and the consequent rough treatment doubtless increased the bacterial count in its effluent, as well as in the combined effluent of Nos. 1 and 2. After 11.15 a.m., November 17, filter No. 1, was also being subjected to drop tests. Filter No. 2 was washed at 10.15 a.m. November 18 and both filters operated uniformly until 11.00 a.m. The sample then taken from the power house tap, and that from the Controller No. 1 show satisfactory counts. Samples of raw, coagulated and filtered water from the power house tap were collected at noon, November 18, and shipped to the laboratory where they were plated and fermentation tubes inoculated. The results indicate a satisfactory effluent.

The results indicate that a 5-minute period of filtering to waste after washing will give a satisfactory effluent during periods of low turbidity. The alum

FIG. 7. FILTER HOUSE AND SEDIMENTATION BASINS FROM THE SOUTHEAST

FIG. 8. OLD (BRICK) FILTER ROOM—NEW FILTER HOUSE AND SEDIMENTATION BASIN AND RIVERSIDE INTAKE WELL. (FROM SOUTH)

COUNCIL GROVE WATER SUPPLY CO.

Filter Plant Daily Record for Week beginning Sunday....., 19...

Day	Temperature Air high	Temperature Air low	Temperature Water raw	Temperature Water filt.	Alkalinity raw	Alkalinity Filtrate	Turbidity raw	Turbidity Filtrate	Clear water in ft's/24 hr. Start of filtering	Clear water in ft's/24 hr. End of filtering	Washing (totals) #1 Times	#1 Minutes	#2 Times	#2 Minutes	Pressure Times	Pressure Minutes
Sun.																
Mon.																
Tues.																
Wed.																
Thurs.																
Fri.																
Sat.																
Week																

Day	Time of operating Filters #1 (gravity) from	#1 (gravity) to	#2 (gravity) from	#2 (gravity) to	Pressure from	Pressure to	Total Hours	Filtering Rate (in 1000 gal. per 24 hours) #1	#2	Pressure
Sun.										
Mon.										
Tues.										
Wed.										
Thurs.										
Fri.										
Sat.										
					Week total					

Day	Alum lbs.	Alum gr. p.m. per gal.	Alum Orifice settings Suction	Basin 1	Basin 2	Intake	Total	Lime lbs.	Hypochlorite lbs.	Hypochlorite lbs. per million gal.	Remarks
Sun.											
Mon.											
Tues.											
Wed.											
Thurs.											
Fri.											
Sat.											
Week											

Supt.

FIG. 9

dose probably may safely be reduced to 1 grain per gallon introduced between compartments 2 and 3, with a secondary dose of ¾ to 1 grain per gallon in the influent line for two hours after starting a run during such period of low turbidity. A marked decrease in the raw water temperature from that noted during the test, 6 degrees C., may necessitate the introduction of the dose at the pump suction.

During periods of high turbidity, it will be necessary for the operator to experiment with the amount and points of introduction of the alum dose, in order that a method of treatment which will effect the most economical and efficient coöperation between settling basin and filters may be obtained. Turbidity and alkalinity readings should be taken daily or oftener and the amount of doses and points of application recorded for future guidance.

Until absolute certainty in operation is attained, hypochlorite should be kept on hand and used in doses of 8 to 10 pounds per million gallons filtered, whenever there is any question as to the quality of the effluent. I believe that the filters are capable of delivering a pure and wholesome effluent with proper operation, and I recommend that they be accepted on condition that adequate effluent controllers be provided.

The engineers of the filter manufacturers, the Kansas State Board of Health and Messrs. Alvah Smith and Arthur E. Smith (the latter representing the writer's firm on the work) all took a very active and helpful interest during design, construction and testing.

As the water company may find possible, without undue expense, further testing will be carried out, while constant record will be kept of the more salient features that may prove helpful also in the treatment of other western waters.

The forms for daily records (Fig. 9) are not as complete as would be the case if a much larger plant was involved and a chemist kept employed, but the very careful superintendent (Mr. A. Moser, Jr.) has already done much experimenting, and engineers from the Kansas State Department of Health, Division of Water, will make frequent visits and make bacteriological tests from samples then taken, so that the station may quite well become of value, not alone to Council Grove, but in helping to solve some of the trying problems of water purification.

AIR BOUND FILTERS

By James M. Caird

There is very little literature on troubles encountered in the operation of water purification plants. The collection of air within a filter bed is a very serious matter and up to the present time the writer is not aware of any method which will successfully prevent this trouble.

The writer's idea as to the cause of air bound filters is as follows:

1st, The lower the temperature of water, the greater the volume of air it may contain.

2nd, During cold weather, water is usually saturated with air.

3rd, Water in passing through filters increases in temperature, liberating air.

4th, The voids in the gravel are greater than in the sand, therefore the air collects in the gravel.

5th, The weight of the sand in American type filters is not sufficient to hold the air in the gravel, therefore the sand beds become perforated.

6th, The weight and fineness of the sand in English type filters are such that it holds the air in the gravel, hence the filter is unable to pass water.

The action of collected air in the American type filter is entirely different from the action in English filters. In both types of filters the trouble seems to be due to the collection of air in the gravel just below the sand layer. Air bound troubles seem to be most frequent when the temperature of the unfiltered water is below 50°F.

In filters of the American type the air seems to collect below the sand until it forces its way up through the sand, perforating the bed, which of course results in imperfect filtration. In filters of the English type, the air collects in the gravel, but does not seem to be of sufficient quantity to force its way up through the bed; but it overcomes the head of water and prevents any water passing the bed.

It may be of interest to consider the air bound conditions in some places.

In the *Annual Reports of the Board of Water Commissioners*, Harrisburg, Pennsylvania, for the years 1907, 1908, 1909 mention is made of the troubles due to air collecting in the filters. The Harrisburg filters are of the American gravity type. The troubles at Harrisburg always come during the cold weather when the temperature of the water is low and the color and turbidity content of the unfiltered water are at a minimum. At such times the air collects in sufficient quantity in the gravel to force its way up through the sand, perforating the bed, and permitting undesirable water to pass. During such periods extra care is used in operating the plant and frequent inspection is made of the loss of head gauges which show when it is advisable to remove the air from the beds. When there is a loss of head of about 3.5 feet, it is advisable to put the bed out of service and apply the wash water for about two minutes, which removes the entrained air. When the air troubles exist the filters are usually given one of these short washes between the regular washes, the beds are then agitated by air. By using this method of operation it has been possible to get good filtration results.

At Bangor, Maine, where filters of the American gravity type are operating on a water which changes very slightly in composition, it is found that it is necessary to reduce the periods very materially between washings during the winter months. At Bangor, when the temperature of the unfiltered water falls to 48° F. the operator begins to reduce the periods of time between filter washings, disregarding the indicated loss of head. In winter the periods between washings are at least 50 per cent less than in summer when the temperature of the water is about 70° F. This method of operation has been very successful. These conditions are mentioned simply as illustrations and are not alone peculiar to these places.

At Wilmington, Delaware, where filters of the English type are operated at a rate of six or seven million gallons per acre per day, air has been the cause of very serious trouble. In the *Annual Reports of the Water Department*, Wilmington, Delaware, for 1911–1912, 1912–1913, 1913–1914 mention is made of the troubles caused by air bound filters. In the Wilmington case it has been necessary, at times, to "by-pass" settled water because the collected air would completely prevent filtration. If it were not for the fact, that all of the water is treated with liquid chlorine before being delivered to the consumers, the grave danger of "by-passing" would almost

amount to murder. As with the filters of the American type, the air troubles at Wilmington come when the temperature of the water is about 45° F. or below. The Wilmington filters are covered and it is found that the temperature of the water increases in passing the filter beds.

For some time past a study of the relation of the dissolved oxygen content of the unfiltered and filtered waters to the air binding of the beds has been made.

Table showing average monthly temperature, dissolved oxygen in per cent saturation before and after filtration and per cent removed, Wilmington, Del.

DATE	TEMPERATURE	PER CENT SATURATION		PER CENT REMOVED
		Before	After	
1913	*Degrees F.*			
October	60.5	90.79	65.43	27.9
November	48.5	95.06	81.54	14.3
December	40.2	97.76	85.94	12.1
1914				
January	34.6	94.18	84.07	11.3
February	35.6	96.97	84.29	13.1
March	37.8	97.39	88.30	9.4
April	52.6	94.19	70.09	25.6
May	66.0	91.49	51.75	43.5
June	74.6	97.08	39.03	59.8
July	76.2	84.70	42.70	49.6
August	77.2	87.20	43.80	49.8
September	70.0	95.20	63.20	33.7
October	62.7	87.80	61.10	30.8
November	46.4	96.80	82.90	14.4
December	37.6	100.00	90.90	9.1
1915				
January	37.4	100.00	90.80	9.2

In March and December, 1914, there were serious troubles, due to air in the beds. It is to be noted that these troubles followed a period of low temperatures of the water before filtration and that the water was about saturated with oxygen. It is also to be noted that the per cent of dissolved oxygen removed at these times is very low.

When the filters are air bound, if a bar be driven through the sand to the gravel layer, and then removed, large volumes of air will

escape. Reducing the head of water over the sand surface does not permit the air to escape.

Up to the present time the best method used to overcome this trouble is to back wash the filter bed. In doing this it is necessary to use great care so as not to displace the sand layers. This procedure of course reduces the bacterial efficiency of the filter.

PIPE DISTRIBUTION SYSTEMS[1]

By Nicholas S. Hill, Jr.

Part I

A STUDY OF CONSIDERATIONS AFFECTING THE DESIGN OF PIPE DISTRIBUTION SYSTEMS

The occasions on which an engineer is called upon to design a distribution system "de novo" for a city of considerable size are very rare. The problem usually presented to him for solution is the design of extensions or reinforcements in an existing system with a view of improving existing pressure conditions, particularly at times of fire.

Before entering either upon the design of a new distribution system or upon the preparation of plans for the improvement of an existing one, the engineer will be called upon to consider local conditions and decide a number of preliminary questions which will affect the problem which he undertakes to solve, and hence the subsequent design.

PRELIMINARY DATA

One of the first steps preliminary to the study of a distribution system is to secure or prepare a base map of the community to be served. If possible to secure, the map should show the city and ward boundaries; present and proposed street lines, and the location of railroads and street railways. It is desirable also to obtain a contour map indicating relative elevations in the city and its environs, and the designer should have, either through the medium of a contour map or from other sources, so that the information can be added to the base map, knowledge of the elevation at street intersections. Information to be added to base maps thus secured should include the location of railroad water tanks, large industrial plants, commercial and business sections, and large fire hazards.

[1]Read and discussed at the Philadelphia convention, and now published, in revised form, for the first time. Open for discussion at the Cincinnati convention or by letter.

One base map should also be used for the purpose of showing the streets which contain improved pavements or other structures which will add to the cost of pipe laying.

In problems involving the improvement of an existing system, a map should be prepared showing the location and size of existing mains exceeding 8 inches in diameter, as well as the location of hydrants, pumping stations, filter plants, distributing reservoirs, standpipes, water tanks and towers, and the like.

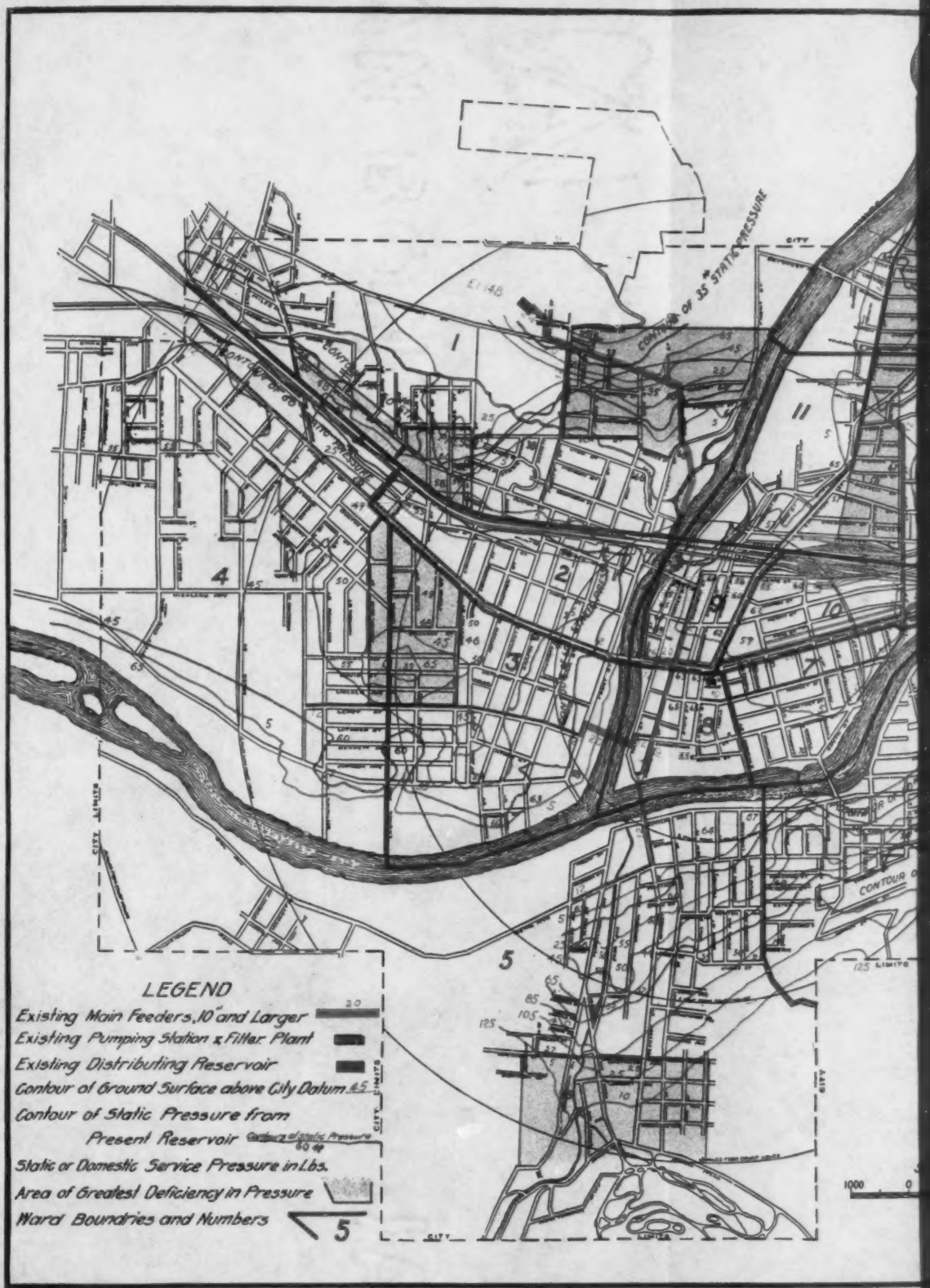
Maps Nos. 1 and 2 presented herewith contain the more important data which should be made available in this form.

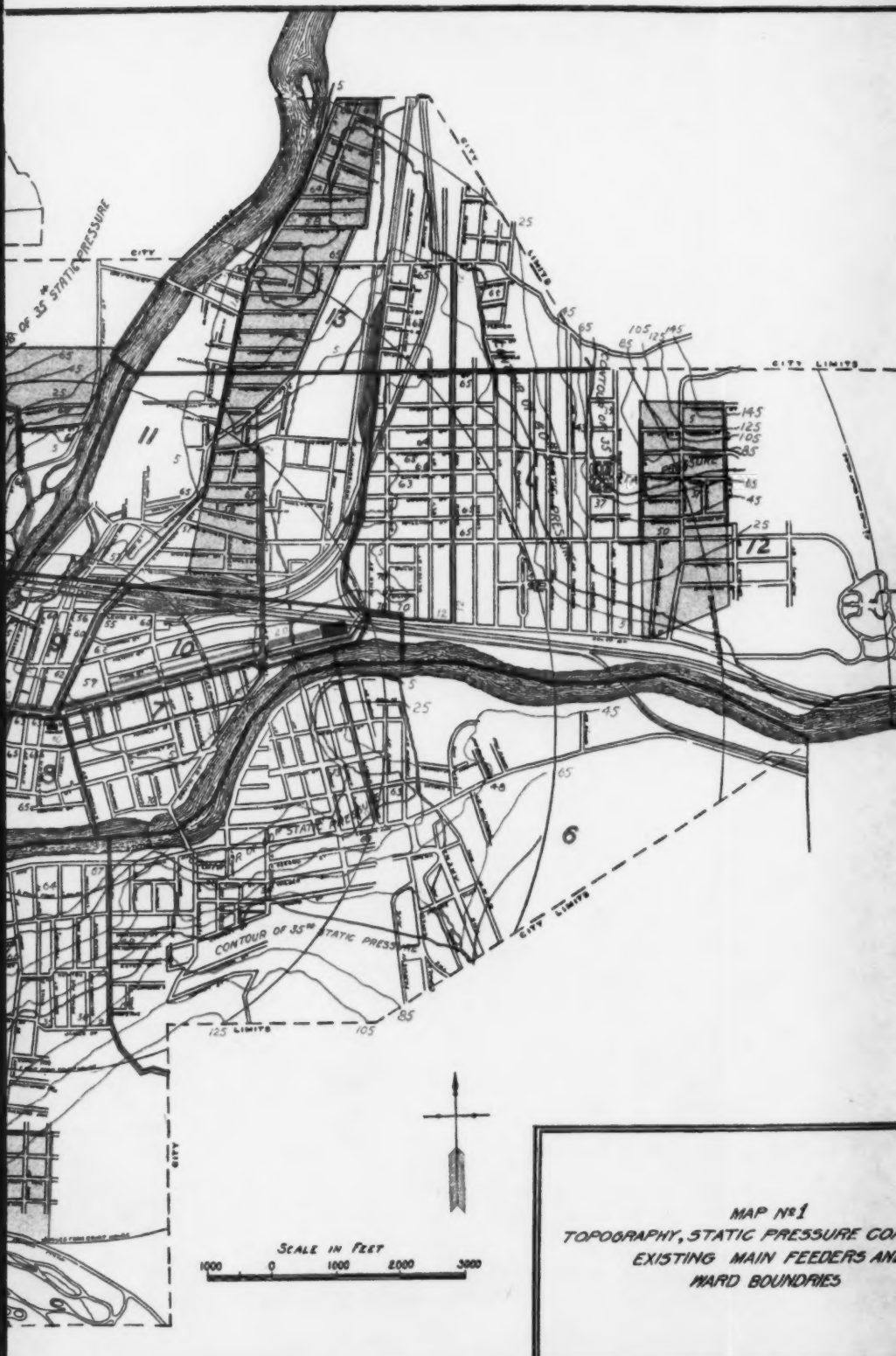
In addition to the data available in the form of maps, the designer should secure by local inquiry, inspection, or test, certain statistical data relating to the existing plant, including the capacity of pumping stations and equipment, filter plants, reservoirs, and critical elevations in and about the same; steam and water pressures which are and may be carried at the existing pumping stations; weight, average age, and interior condition of cast iron pipe in the existing distribution system; number of service taps and meters in use; population and water consumption statistics.

He should also have before him the results of tests made on existing hydrants, showing the pressures which obtain in various parts of the community on the date of the design, under both fire and ordinary domestic service conditions, and he should possess a general familiarity with the density and character of the dwellings in different parts of the city.

FUTURE PERIOD CONSIDERED

After having secured or prepared the necessary maps and obtained the necessary data, the engineer must consider and decide upon the future period for which the contemplated improvements are to serve without duplication or enlargement. This period will bear no relation to the useful life of cast iron pipe, which depends largely on the service for which it is used and may exceed a hundred years. It would manifestly be impossible to predict the amount or direction of a city's growth for so long a period as a hundred years with any degree of certainty. It is possible, however, to predict with sufficient accuracy, both the extent and distribution of population growth, upon which the future demand for water will in great measure depend, for a period of twenty to thirty years to come.


LEGEND
Existing Main Feeders, 10" and Larger
Existing Pumping Station & Filter Plant
Existing Distributing Reservoir
Contour of Ground Surface above City Datum
Contour of Static Pressure from Present Reservoir
Static or Domestic Service Pressure in Lbs.
Area of Greatest Deficiency in Pressure
Ward Boundries and Numbers
CONTOUR OF 35# STATIC PRESSURE
CITY LIMITS
1000

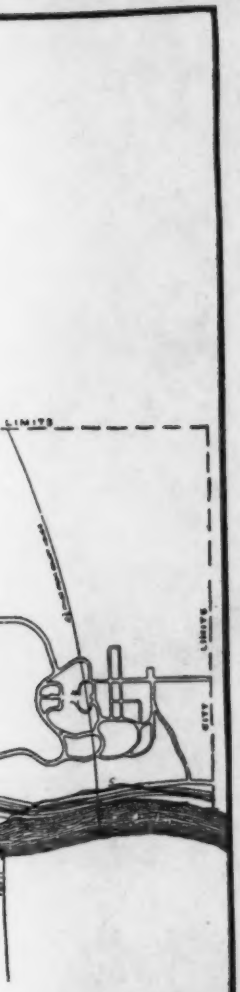


MAP No 1

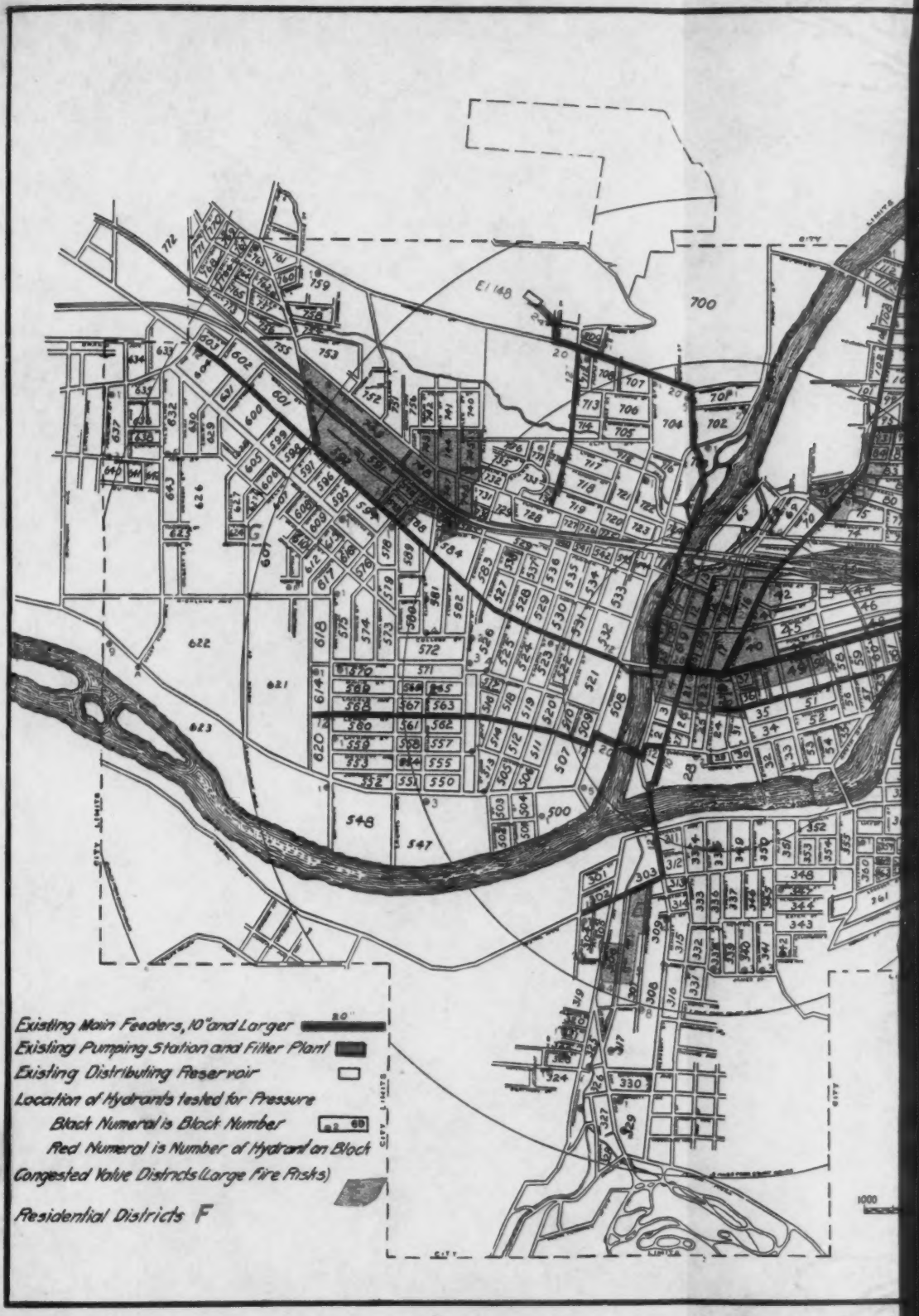
TOPOGRAPHY, STATIC PRESSURE CO

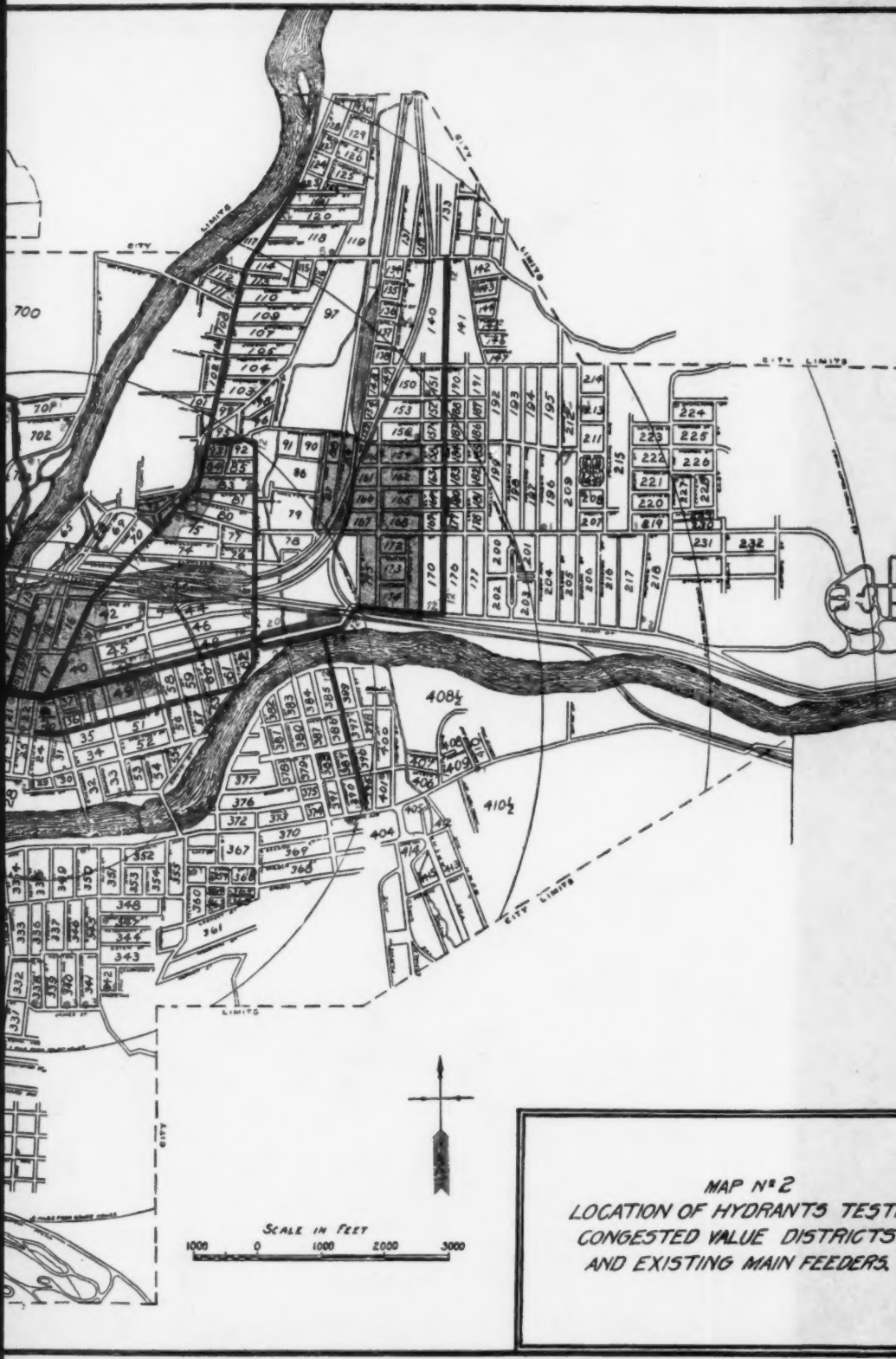
EXISTING MAIN FEEDERS AN

WARD BOUNDRIES



1
ESSURE CONTOURS,
EEDERS AND
ORIES


El 1148
Existing Main Feeders, 10" and Larger
20"
Existing Pumping Station and Filter Plant
Existing Distributing Reservoir
Location of Hydrants tested for Pressure
Block Numeral is Block Number
Red Numeral is Number of Hydrant on Block
Congested Value Districts (Large Fire Risks)
Residential Districts F
1000



MAP Nº 2

LOCATION OF HYDRANTS TEST
CONGESTED VALUE DISTRICTS
AND EXISTING MAIN FEEDERS.

TS TESTED,
STRICTS
FEEDERS.

The reasons for predicating estimates on results which are expected to obtain so far in the future are not that one can undertake to forecast the future with mathematical exactness even for this limited period, but rather because it is the safest and most rational way in which to make reasonable provision for future needs.

Failure to make such provision frequently results in a high capital investment in mains. It is cheaper to lay a main which is too large for present needs than to lay one which must be reinforced within a few years. To show the expense which a company or city incurs by pursuing such a policy. Table No. 1 is presented, which shows the comparative cost of different pipe sizes to give the same service.

The costs given in the table do not and, of course, can not take into consideration the damage to improved streets, and the additional cost of maintaining them, which results from continual tearing up, nor can they take into account the inconvenience, annoyance and the disturbance of traffic which results from repeated removal of the street surface. They further do not include the additional cost of repairs due to the increased main mileage which results from duplication of mains and the increased liability of having to excavate for repairs, nor any consideration of the enhanced pumping costs ensuing from greater main leakage resulting from an increase in the number of pipe joints. The table clearly shows that even where the period of usefulness of the first main laid is eighteen out of twenty-six years, the saving in favor of two mains in most cases is not sufficient to offset the other losses incurred.

POPULATION

Having determined upon the future period to be considered, the next question to arise will be the probable future population of the community to be served. All estimates of future population are based to a greater or less extent upon past growth. Proper regard must be had, however, for special conditions which have tended abnormally to accelerate or retard the rate of growth prior to the date of the design so that proper allowance may be made in the assumed or computed future rate of increase. The percentage growth in communities generally decreases as the population increases, although the total annual increase may be greater in each successive year. It is not always safe, therefore, to apply percentages based on past growth to estimates of the future growth. It has been

TABLE No. 1

Comparative cost per foot, different pipe sizes to give same service

DIAMETER OF PIPE REQUIRED TO SUPPLY THE SERVICE FOR PERIOD OF 20 YEARS	NUMBER AND SIZE OF SMALLER PIPES REQUIRED TO GIVE SAME SERVICE AS SINGLE PIPE OPPOSITE IN COL. (1)	INITIAL COST, CLASS C PIPE, @ $25.00 PER TON IN MEDIUM DIGGING WITH LABOR @ $1.75 PER 10 HR. DAY		ASSUMED NUMBER OF YEARS DURING WHICH A SINGLE PIPE OF DIAMETER GIVEN IN COL. (2) WILL SUFFICE	RELATIVE ANNUAL COSTS PER FOOT UNDER FOLLOWING PLANS						CAPITALIZED ANNUAL COST				SAVING IN FAVOR OF PLAN 1,—THE IMMEDIATE INSTALLATION OF LARGER PIPE	
					Plan 1 Immediate installation of single pipe of size given in col. (1)			Plan 2 Immediate installation of single pipe of size given in col. (2) to be followed after expiration of period given in col. (5) by installation of second pipe of same size			Plan 1	Plan 2				
		Single pipe of diameter given in col. (1)	Single pipe of diameter given in col. (2)		Interest on initial cost @ 5 per cent	Annuity required to amortize capital investment at end of 70 year life @ 4 per cent	Total annual cost per foot	Interest on initial cost of one pipe @ 5 per cent	Annuity required to amortize capital investment at end of 70 year life @ 4 per cent	Total annual cost per foot of one pipe	Total annual cost per foot as given in col. (8) capitalized at 5 per cent	Total annual cost per foot of first pipe as given in col. (11) capitalized @ 5 per cent	Present value of total annual cost per foot of second pipe as given in col. (11) when capitalized @ 5 per cent	Total	Amount in dollars per foot	In per cent of cost of plan 1
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
					= (3) ×.05	= (3) ×.00274	= (6) + (7)	= (4) ×.05	= (4) ×.00274	= (9) + (10)	= (8) +.05	= (11) +.05	=(11)÷.05 reduced to present value	= (13) + (14)	= (15) − (12)	= (16) ÷ (12)
inches	*inches*	$	$		¢	¢	¢	¢	¢	¢	$	$	$	$	$	%
24	2.05–18	4.61	2.87	6	23.05	1.26	24.31	14.35	0.79	15.14	4.86	3.03	2.26	5.29	0.43	8.8
				12	23.05	1.26	24.31	14.35	0.79	15.14	4.86	3.03	1.69	4.72	−0.14	−2.9
				18	23.05	1.26	24.31	14.35	0.79	15.14	4.86	3.03	1.26	4.29	−0.57	−11.7
16	2.05–12	2.42	1.59	6	12.10	0.66	12.76	7.95	0.44	8.39	2.55	1.68	1.25	2.93	0.38	14.9
				12	12.10	0.66	12.76	7.95	0.44	8.39	2.55	1.68	0.94	2.62	0.07	2.7
				18	12.10	0.66	12.76	7.95	0.44	8.39	2.55	1.68	0.70	2.38	−0.17	−6.7
8	2.05–6	0.96	0.69	6	4.80	0.26	5.06	3.45	0.19	3.64	1.01	0.73	0.54	1.27	0.26	25.7
				12	4.80	0.26	5.06	3.45	0.19	3.64	1.01	0.73	0.41	1.14	0.13	12.9
				18	4.80	0.26	5.06	3.45	0.19	3.64	1.01	0.73	0.30	1.03	0.02	2.0

the practice in the office of the author of this paper not only to base estimates of future growth upon the past increase of population, but to check such estimates by comparing the estimated growth during, say, the next twenty years with the past growth of similarly located towns whose population twenty years ago was about equal to the present population of the town under consideration.

Several methods of estimating future growth may be used. They may be designated as follows: arithmetical progression method; comparative method; incremental increase method; geometrical progression method.

Arithmetical progression method

This method is applicable only in rare cases and almost uniformly produces estimates which are too low. The method, as its name implies, involves the assumption that the future rate of increase from year to year will be constant, and the same as has obtained in the past, or for some period which may be selected at the choice of the computor.

Comparative method

The comparative method involves the selection of cities, similarly situated, whose population, say twenty years ago, was practically the same as the present population of the town under study. The past growth of such towns is then taken fairly to represent the probable future growth of the one in question.

Incremental increase method

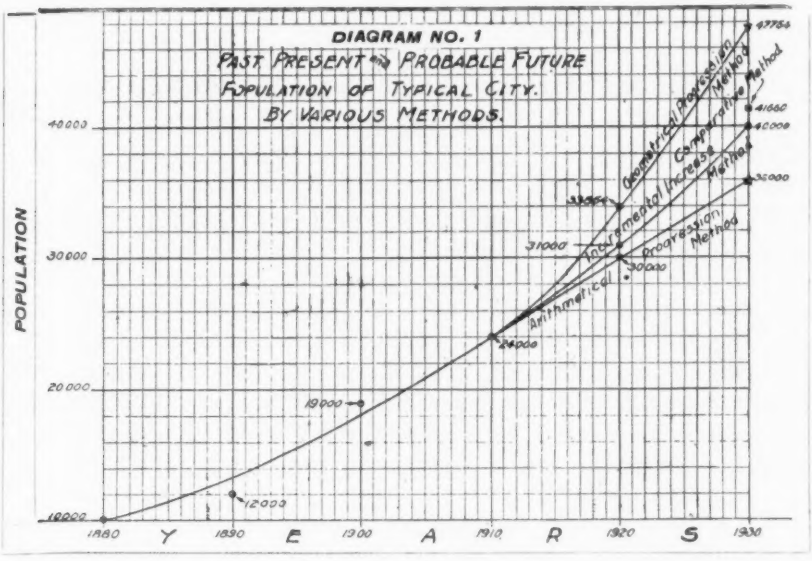
By the incremental increase method, the population of a town by decades is ascertained as far back as records have been kept. The actual gross increase in population from decade to decade is determined. Then the increase in the increase is determined, or the increment of increase for each decade. The actual increase as determined for each decade is averaged, and also the increment of increase. In making the estimates of future population, the population at the end of the first future decade is obtained by adding to the present population the average increase plus the average increment per decade thus found, and the future population at the end of the second decade by adding to the estimated population at the end of the first future decade, the average increase, plus twice the average increment, and so on.

Geometrical progression method

The geometrical progression method involves the determination of the compound rate at which the population of a city has increased in the past, then applying this compound rate to the present population, to determine the future growth.

Comparison of methods

The curves on Diagram No. 1 give the results of applying each of the four methods outlined to the population of a typical



city. The population between 1880 and 1910 as expressed by the curve is that returned by the census. The populations from 1910 to 1930 are those computed by the four methods.

It will be noted that the incremental increase method is about a mean of the several methods, and experience has shown that it frequently falls in this way in towns of normal growth. No single method, however, is applicable to all conditions and judgment must be exercised in estimating future population.

DISTRIBUTION OF POPULATION

The preceding methods are those commonly employed in estimating the future population of the community as a whole, but it

is desirable to subdivide the total population by districts in order that the size of the pipe intended to supply individual localities may be proportioned intelligently.

Whereas the commercial and manufacturing use of water and the water required for fire service are practically independent of the distribution of population, the domestic and public demand for water follows the distribution of population very closely and, therefore, a study of the distribution of population enables one to make a reasonably intelligent estimate of the probable local demands for water for the last two purposes named. After the local demand for water required for domestic and public uses has been determined through the study of population distribution, the water required for manufacturing, commercial and fire purposes in the sub-divisions used for localizing the domestic and public supply may be added from knowledge of the specific use of water for commercial, manufacturing and fire purposes in those districts.

A distribution system to be economically built must be designed to meet the conditions of some future year. In this year the distribution of population may, and usually will, be quite different from the distribution on the date of design. On the date of design some districts may be fully built up, and it would obviously be erroneous to assume that the future domestic and public water requirements in such districts will increase in the same proportion as for growing districts, or as for the city as a whole. It is possible, however, for the designer to establish a reasonable figure representing the probable density of population in any section in the city considered. He may then in apportioning the total future population by districts avoid exceeding this figure in any built up district, and by the exercise of a little judgment and with a knowledge of the local conditions, apportion the balance of the total growth to the more sparsely settled districts and thus obtain a fairly accurate future distribution of population, and hence of domestic and public water consumption.

Subdivision by wards is convenient for the purpose of apportioning local consumption in different districts and may be made without difficulty as the ward populations are usually given in the census returns.

Where ward boundaries include large areas, a further subdivision may be made, if desired, by estimating the population by registration districts. Knowing the total registration in a given city or

ward in a given year, and the population in the same year, a ratio may be established between the population and the number of registered voters. By applying this ratio to the number of registered voters in a given registration district, its population may be closely approximated. This refinement, however, is not usually necessary.

CONSUMERS

Having decided upon the probable rate of growth and distribution of future population in the territory to be supplied, it will be necessary before proceeding with estimates of domestic and public water consumption to determine the future population which will probably require to be served with water. The percentage of the total population actually connected with the public supply seldom exceeds 90 to 95 per cent, and may be much less than this, depending upon local conditions and upon the individual characteristics of the community. The desirability of basing estimates of future domestic consumption upon the probable number of water consumers, rather than upon the probable total population is, therefore, apparent.

With new installations there is usually a period of rapid growth extending over several years in which the per cent which the number of consumers bear to the total population increases rapidly from zero to a comparatively large figure. Following this development period it is not uncommon for the per cent of consumers to increase at a gradually retarded rate until 90 to 95 per cent are connected with the mains.

In designing extensions to existing systems it usually is possible to ascertain the number of consumers in present and past years, to establish the ratio between the number of these consumers and the total population, and from a study of the past in the light of knowledge of local conditions to forecast with sufficient accuracy the probable future relation between consumers and population. With this relation fixed the number of future consumers may be estimated from the previously estimated future population.

The number of actual consumers in any past year usually may be estimated most satisfactorily by ascertaining the number of service taps, or first connections, carried on the books of a company, and applying to this number a factor representing the average population per tap or per house in the community considered. In small

cities and in suburban communities this factor will usually be in the neighborhood of 5, though it may in rare instances be as low as 3, and in cities large enough to contain many apartment or tenement houses will be much greater.

The ratio between total population and the number of registered voters may sometimes be useful in determining the proper factor to use in a given community where most of the houses are occupied by not more than one family, while in the larger cities the establishment of the ratio will not be so important since in these the number of consumers will usually comprise a very large percentage of the population, and may be estimated directly.

In designing entirely new systems, the designer will be obliged to assume the probable per cent of the total population which will be served in future years, though he may be guided in forming this judgment by his knowledge of local conditions and by the values known to obtain in communities and under conditions similar to those which he has under consideration.

WATER CONSUMPTION

The next important element affecting the design of a distribution system is the average or normal quantity of water required to be delivered therethrough, and the fluctuations or variations from the normal which may be anticipated from various causes. For the sake of clearness, we will first discuss the average or normal demands and then the fluctuations which may occur.

Average or Normal Consumption of Water

The normal water consumption may be divided into four components:

a. Domestic consumption.

b. Water required for municipal and public purposes, including fire service.

c. Industrial and commercial use.

d. Water unaccounted for.

The relative importance of each component varies widely with the character and size of a community. In small villages the quantity of water required for domestic use, as compared with the quantity which the mains must deliver in time of fire, will be so small as to be almost neglible. In large cities, the reverse will be true,

while in some places the requirements for railroad or industrial uses may greatly outweigh the ordinary domestic and fire service requirements. These facts are well illustrated by Table No. 2. The maximum of the several demands may occur simultaneously, or the maximum of one or more may coincide with the minimum or average of one or more of the others.

TABLE No. 2

Relation between commercial and industrial consumption; water consumed for domestic and public purposes and wasted; and maximum fire demands in various communities

YEAR TO WHICH DATA APPLIES	COMMUNITY	POPULATION	RATE OF CONSUMPTION PER CAPITA						
			TOTAL	DOMESTIC AND PUBLIC PURPOSES AND WASTE		COMMERCIAL AND INDUSTRIAL		MAXIMUM FIRE DEMAND FREEMAN'S MINIMUM	
				Gallons daily	Per cent of total	Gallons daily	Per cent of total	Gallons daily	Per cent of total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1906	East Greenwich, R. I.	3,750	68.6	30.4	44.3	38.2	55.7	384.0	559.0
1906	Patchogue, L. I.....	3,800	112.0	43.0	38.4	69.0	61.6	384.0	342.8
1909	Rochester and Lake Ontario Water Company..	7,100	420.2	113.4	27.0	306.8	73.0	253.0	60.2
1913	Woodhaven, L. I.....	30,000	66.5	57.9	87.1	8.6	12.9	120.0	180.4
1911	Jamaica, L. I.	42,000	95.9	88.8	92.6	7.1	7.4	103.0	107.4
1908	Boston, Mass[1]	643,810	153.0	125.3	81.9	27.7[2]	18.1	35.8	23.4

[1] *Journal New England Water Works Association*, Vol. 27, No. 1, p. 102.
[2] Meter only.

Domestic Consumption

The quantity of water required for domestic purposes is a function of the number of consumers, although very marked differences are observable in different communities in the actual consumption of water per consumer for domestic purposes, which, after making all due allowance for the presence or absence of meters, are indicative of marked characteristic demands in the individual community for the legitimate use of water for domestic purposes.

Table No. 3 gives in column 5, the domestic consumption of water per consumer per day in various places. The figures as given have

TABLE No. 3

Data relating to consumption of water for domestic and public purposes

NAME OF PLACE OR COMPANY	TOTAL POPULATION CENSUS OF 1910	NUMBER OF DOMESTIC SERVICES MEASURED	ESTIMATED NUMBER OF DOMESTIC CONSUMERS MEASURED	DOMESTIC CONSUMPTION GALLONS DAILY PER CONSUMER	FREE CONSUMPTION PUBLIC PURPOSES. GALLONS DAILY PER CAPITA
(1)	(2)	(3)	(4)	(5)	(6)
Massachusetts:					
Metropolitan Water District of Boston	1,022,230		53799	33.0	7.11
Brockton[2]	56,878			15.5	3.00
Brookline	27,792				13.05
Chelsea	32,452		13937	26.1	
Everett	33,484		395	33.1	
Fall River	119,295				12.79
Lawrence[3]	85,892			17.0	5.00
Malden	44,484		37994	17.6	
Quincy	32,642		8391	25.6	
Revere	18,219		938	36.6	
Somerville	17,236		26234	25.6	
Swampscott	6,204		2871	34.7	
Watertown	12,875		11299	16.7	
Worcester	145,986		3716	44.0	
Rhode Island:					
East Greenwich	3,420		3420	30.4	
Woonsocket	38,125				5.57
Connecticut:					
Hartford[2]	98,915			30.0	5.00
New York:					
Canandaigua	7,217				12.25
Elmira	37,176	2124	12107	19.6	
Geneva	[4]14,000	2481	12500	20.0	
Patchogue	3,824		3824	43.0	
Syracuse[3]	137,249			31.0	18.00
Yonkers	79,803			[1]20.0	5.00
New Jersey:					
East Orange	34,371	3545	18350	58.5	2.00
Montclair	24,426			35.0	
Pennsylvania					
Harrisburg[3]	64,186			30.0	5.00
Pennsylvania Water Co.		2000	10000	21.4	

[1] Report of Water Board, 1904.
[2] Journal of N. E. W. W. Ass'n., March, 1913.
[3] Superintendents' Estimate.
[4] Local Estimate.

TABLE No. 3—Continued

NAME OF PLACE OR COMPANY	TOTAL POPULATION CENSUS OF 1910	NUMBER OF DOMESTIC SERVICES MEASURED	ESTIMATED NUMBER OF DOMESTIC COMSUMERS MEASURED	DOMESTIC CONSUMPTION GALLONS DAILY PER CONSUMER	FREE CONSUMPTION PUBLIC PURPOSES. GALLONS DAILY PER CAPITA
(1)	(2)	(3)	(4)	(5)	(6)
Pennsylvania—*Continued*					
Pittsburgh	533,905	390	1950	35.0	
Vicinity of Pittsburgh		4801	24005	23.0	
Six Other Places in Vicinity of Pittsburgh		17222	86110	20.0	
Ohio:					
Cincinnati	363,591	8245	65960	58.8	7.00
Illinois:					
Peoria	66,950		744	52.0	
Louisiana:					
New Orleans	339,075			35.0	

been obtained from different sources and largely from the Report of the Committee on Water Consumption of the New England Water Works Association as published in the *Journal* of that Association for March, 1913. It is seen from the table that the per consumer consumption of water for domestic purposes in the places listed varies between 15.5 gallons and 58.5 gallons, or by about 360 per cent. It is important that a designer bear this fact in mind and not attempt to force town A to struggle along on 20 gallons per capita for domestic consumption because town B, a thousand miles away, is able to do so.

Water Required for Municipal and Public Purposes

The water required for free public purposes is also given on the preceding table and varies between 2 and 18 gallons daily per capita. Probably an average allowance of 10 gallons daily per capita will be safe in providing for a new system of mains or for reinforcements to an existing system. Although the quantity of water required for these purposes is more properly a function of the total population in the territory supplied than of the number of water consumers in that territory, in most instances no serious error will be introduced by estimating it on the basis of the number of gallons daily required per consumer.

The water consumed for fire purposes is included in the amounts given for free public purposes, but to consider the requirements for fire fighting as a percentage of total consumption, or in gallons per capita or per consumer is grossly misleading for the reason that this fire service comes as a peak load, at long intervals and lasting for but short periods. When these peak loads occur, the demands for fire service may and do, in small communities, represent a quantity often as great, or greater than, the total average daily demand for water, so that special estimates must be made for the purpose of determining the maximum fire draft under given conditions in order properly to design the distribution system. Such estimates fall in the category of fluctuations rather than average demand, and will be estimated separately.

Industrial and Commercial Use

So far as the industrial and commercial consumption is concerned, the ratio of the demand for this purpose to the total demand varies so radically in different places, depending upon the extent of the commercial and industrial interests, that it is not possible to give figures representing a proper allowance for it. It is necessary, in each individual instance, to determine the amount of water at present used for such purposes. This is one of the unknown factors that can be ascertained only by a local survey. The range of consumption for industrial and commercial purposes is from zero in suburban residential districts to 80 or 100 gallons per capita in large manufacturing centers where the processes employed create a heavy demand for water. Even after the present quantity of water used for industrial and commercial purposes has been ascertained by survey there will remain the difficulty of forecasting what this quantity will be in the future as the growth in these requirements frequently bears a rather indefinite relation to the growth of population. It may sometimes be desirable, especially in the case of railroads and of very large industrial concerns, to make individual forecasts of their future needs, basing the judgment upon knowledge of local conditions, inquiries made of the owners or officers of the various companies, etc. In many instances, however, it will be safe to assume that the growth in the requirements of existing industrial and commercial concerns will increase in the same ratio as the population.

In whatever way the future needs of these existing concerns is estimated, some additional allowance should be made for plants which are not extant at the date of the design.

In some instances it may be necessary to take account of the manner in which the daily railroad, industrial and commercial use of water is distributed over the twenty-four hours. If an industrial plant using 500,000 gallons of water per day operates only twelve hours out of the twenty-four, its effective consumption, so far as the required main carrying capacity is concerned, will be at the rate of 1,000,000 gallons per day. As was the case with the fire service flows, however, these estimates fall in the category of fluctuations rather than of average demand and should be estimated separately.

Water Unaccounted for

The water unaccounted for includes that wasted. The water wasted varies materially in different communities, probably, in general, between the limits of 20 per cent and 40 per cent of the total water supplied. The water unaccounted for and wasted may be divided into:

Metered Supplies	*Unmetered Supplies*
1. That unaccounted for through measurement by plunger displacement of pumps where no allowance is made for slip.	1. That unaccounted for through measurement by plunger displacement of pumps where no allowance is made for slip.
2. That lost through leaky mains and services.	2. That lost through leaky mains and services.
3. That unaccounted for through under-registration of meters.	3. That lost through defective plumbing and house piping.

The pump slippage is a variable quantity, varying from 3 per cent in the best type of pumps which are well maintained, to 65 per cent in pumping engines which are not properly cared for. It is exceedingly common to find a slippage of 10 to 20 per cent in the ordinary pumping station.

The loss of water through mains and services depends upon the care and skill with which the distribution system was installed, the amount of attention which is given to the maintenance of the dis-

tribution system, and upon the relation of main mileage to the total consumption. In general, it may be said to vary between 15 per cent and 30 per cent of the total consumption.

Table No. 4 gives the results of leakage tests on carefully laid cast iron pipe from 4 inches to 36 inches in diameter. It indicates that an average main leakage of 100 gallons per mile per inch of diameter may be expected even in new and unusually well constructed systems. In a system containing 100 miles of pipe averag-

TABLE No. 4

Results of leakage tests on cast iron pipe

CITY	SIZE OF PIPE INCHES	LENGTH OF PIPE TESTED FEET	NUMBER OF TESTS MADE	AVERAGE LEAKAGE GALLONS DAILY PER MILE PER INCH OF DIAMETER	PRESSURE UNDER WHICH TEST WAS MADE POUNDS
(1)	(2)	(3)	(4)	(5)	(6)
Akron, Ohio	4	717	1	23	66 to 152
Reported by E. G. Bradbury, *Engineering Record*, Volume 65, page 432	6	31,066	34	66	66 to 152
	8	6,882	6	42	66 to 152
	10	5,123	5	81	66 to 152
	12	9,704	8	102	66 to 152
	16	8,792	11	135	66 to 152
	20	8,389	10	69	66 to 152
	24	3,358	3	69	66 to 152
	30	14,445	8	82	66 to 152
Total or Average		88,476	86	83.4	66 to 152
Columbus, Ohio Reported by J. H. Gregory, *Engineering News*, Volume 72, page 725	36	16,940	3	422	110

ing 8 inches in diameter this would mean a minimum leakage from mains alone of 80,000 gallons daily, or possibly 5 per cent of the total consumption. In the average system it will be considerably more than this.

Table No. 5 fairly illustrates the water unaccounted for in cities having metered supplies.

An allowance of from 3 to 6 per cent should be made for under registration of meters.

TABLE No. 5

Water unaccounted for in cities with metered supplies

CITY	PER CENT METERED	WATER UNACCOUNTED FOR	
		PER CENT	GALLONS PER DAY PER MILE OF PIPE
(1)	(2)	(3)	(4)
Attleboro, Mass.	(a) 100	53.0	—
Brockton, Mass.	90	32.3	6,200
Fall River, Mass.	96	21.5	10,000
Harrisburg, Pa.	(b) 75±	21.0	—
Hartford, Conn.	(b) 99	39.0	—
Lawrence, Mass.	(b) 87	29.0	—
Madison, Wis.	(a) 97	69.0	—
Needham, Mass.	(a) 95	75.0	—
North Attleboro, Mass.	(a) 100	55.0	—
Providence, R. I.	90	30.0	13,400
Ware, Mass.	100	39.8	11,200
Watertown, Mass.	(a) 94	47.0	—
Wellesley, Mass.	100	41.5	3,450
Winchendon, Mass.	(a) 97	55.0	—
Woonsocket, R. I.	87	23.0	4,370
Worcester, Mass.	94	46.5	20,800
Yonkers, N. Y.	100	45.7	23,340

(a) Data obtained from Table No. 11, p. 136, *Journal New England Water Works Association*, 1907. Paper by W. S. Johnson.

(b) Data obtained from Report of Mr. James H. Fuertes to Merchants Association, New York, 1906.

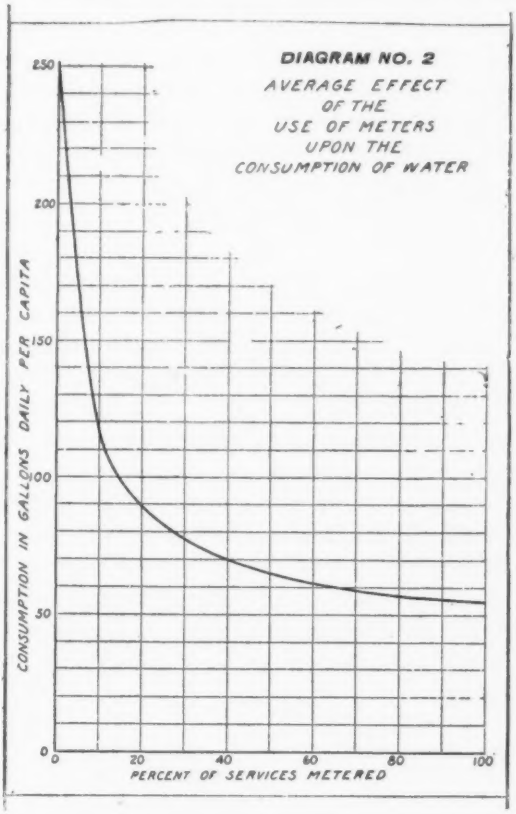
Allowances for the probable quantity of water which will be unaccounted for or wasted in future years may usually be estimated most conveniently as a certain number of gallons per capita or per consumer, the number being based upon present values where ascertainable with due regard for steps which may be taken to reduce existing leakage and waste. The reasonableness of the assumptions thus made should always be checked by calculating what they represent in per cent of total consumption and per mile of pipe.

Effect of Meters in Reducing Waste

The possible reduction of losses due to defective plumbing and to other household waste by the introduction of meters depends upon the care and system with which house-to-house inspections have been made prior to the introduction of meters, as well as upon

the general condition of plumbing which varies greatly in different sections, upon the habits of the people, and in a measure upon climatic conditions.

It is not possible to give a specific statement of the saving which may be effected by meters in a particular community without a deliberate local study. As a general indication of the effect of the



introduction of meters, however, Diagram No. 2, taken from Mr. John R. Freeman's *Report on New York's Water Supply* is presented.

It is dangerous to be too hopeful about the prevention of waste, for, with these hopes unfulfilled and an insufficient distribution system, pressures will be reduced below the point required for satisfactory service.

While the general introduction of domestic meters will usually

result in curtailing household waste, it is inexcusable to place too much reliance upon this expedient while local sentiment is against the domestic meter, and it is poor policy to provide an insufficient distribution system while discussing what ought to be done to educate the public to a greater economy in the use of water.

In providing for the health, comfort, convenience and future prosperity of a community, the engineer must be governed by practical considerations; by what the public will do and not by the theory of what they ought to do; by the efficiency ordinarily attained in municipal departments and not that which should be attained. From the operating and economic viewpoint, waste should be fought and fought hard. Its restriction saves capital outlay for enlarged mains, pumps, filters and reservoirs. It saves operating costs for fuel, coagulants, supplies and labor. A standard of reasonable consumption should be set and its attainment constantly aspired to. From the viewpoint of future requirements, however, sufficient main capacity must be provided so that, under normal conditions, with things and men as we find them, no one shall suffer by reason of his neighbor's waste or the inefficiency of municipal departments. It is well to estimate upon the proper, theoretical, economical per capita consumption as a minimum, and to estimate the future consumption as a reasonably conservative maximum. Nothing will be lost by this, so far as the distribution system is concerned, for the reason that it means only that the mains will have a life of a few years more before replacements or reinforcements are required, and figured on this basis, it matters very little so far as the financial return is concerned whether the pipes as laid are estimated to be large enough for twenty or for twenty-five years.

Effect of Sewers upon Consumption

The presence or absence of sewers will exert a material influence upon the average quantity of water consumed.

Table No. 6 which was obtained from the report of the Committee on Water Consumption previously referred to, gives the average consumption of water in three Massachusetts cities before and after the introduction of a fairly complete system of sewers. As in the case of the introduction of meters, it is not possible to give exact figures representing the probable changes in the use of water

TABLE No. 6

Average consumption of water in three Massachusetts cities before and after the introduction of a fairly complete system of sewers

Gallons per person per day

CITY	YEARS PREVIOUS TO INTRODUCTION OF SEWERS							YEAR WHEN SYSTEM OF SEWERS WAS PRACTICALLY COMPLETED (1891)	YEARS SUBSEQUENT TO INTRODUCTION OF SEWERS									
	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	19
Marlborough.	13	17	20	21	24	24	25	26	30	30	35	34	37	37	38	38	36	37
Newton.	28	31	33	33	31	36	40	43	50	52	60	65	63	60	57	63	62	63
Waltham.....	37	36	39	33	31	32	33	40	47	53	61	59	71	70	76	88	90	88

which will result from the introduction of sewers in a specific place, but the table illustrates, in a general way, that where a system is being designed for a town without sewers, liberal allowance should be made for the subsequent introduction of sewers.

Variations in Average Per Capita Consumption

The total consumption of water in cities and towns varies between wide limits, as is indicated by Table No. 7 and it is necessary for the engineer in designing a system of distribution to study the local and characteristic uses.

TABLE No. 7

Total consumption of water in various metered and unmetered cities in the eastern United States

CITY	POPULATION	DAILY CONSUMPTION	DAILY CONSUMPTION PER CAPITA
(1)	(2)	(3)	(4)
Connecticut:			
Bridgeport.....	112,144	22,428,800	200
Hartford.....	126,582	8,640,000	68
Meriden.....	28,228	2,822,800	100
New Haven.....	141,915	21,287,250	150
New London.....	20,000	3,104,947	155
Stamford.....	28,106	4,215,900	150
Waterbury.....	80,289	7,282,213	91

TABLE No. 7—Continued

CITY	POPULATION	DAILY CONSUMPTION	DAILY CONSUMPTION PER CAPITA
(1)	(2)	(3)	(4)
New York:			
Albany	102,344	22,486,000	220
Auburn	36,071	6,542,189	182
Binghamton	51,300	7,242,286	140
Brooklyn	1,786,327	157,500,000	91
Buffalo	446,889	138,100,000	309
Elmira	37,664	4,970,000	132
Ithaca	15,000	2,000,000	133
Kingston	26,354	6,994,821	266
Middletown	15,570		
Newburgh	28,733	4,128,931	144
New York (Manhattan)	2,487,962	303,000,000	104
Oswego	23,747	4,650,064	196
Poughkeepsie	29,203	2,715,879	93
Rochester	235,968	22,180,992	94
Schenectady	86,305	10,615,515	123
Syracuse	146,480	17,577,600	120
Troy	77,382	21,000,000	271
Yonkers	90,156	8,679,915	96
New Jersey:			
Atlantic City	52,098	12,785,000	245
Camden	100,581	12,572,625	125
Elizabeth	80,272	13,164,608	164
Jersey City	287,709	44,882,607	156
Newark	379,211	38,679,522	102
Passaic	63,542	4,575,024	72
Plainfield	22,231	3,440,000	150
Trenton	104,451	20,000,000‡	191±
Pennsylvania:			
Allegheny	140,200	35,134,120	251
Altoona	55,504	5,200,000	94
Bradford	17,000	2,000,000	117
Erie	71,004	11,050,537	153
Johnstown	62,705	10,032,800	160
Lancaster	49,101	5,900,000	120
Norristown	29,697	2,375,760	80
Philadelphia	1,631,956	290,500,000	178
Pittsburgh	385,100	84,991,570	221
Reading	101,628	13,923,036	138
York	18,318	3,160,000	66

Even in places where a large percent of the services are metered, the variation in per capita consumption is very great. This is indicated by Table No. 8. It will be noted that with a single exception, none of the towns listed in this table, has less than 70 per cent of the services metered, yet the gross per capita consumption varies between 38 and 128. The table is presented to accen-

TABLE No. 8

Variations in total per capita consumption of water in plants having a large percentage of metered services

CITY	PER CENT METERED SERVICES	TOTAL CONSUMPTION GALLONS PER CAPITA
(1)	(2)	(3)
Anniston, Alabama	76	128
Atlanta, Georgia	100	65
Bayonne, New Jersey	100	95
Bessemer, Alabama	70	46
Brockton, Massachusetts	90	38
Cleveland, Ohio	94	100
Consolidated Water Company	85	71
Covington, Kentucky	100	51
Geneva, New York	91	35
Harrisburg, Pennsylvania	83	122
Hartford, Connecticut	98	68
Lexington, Kentucky	98	58
Lincoln, Nebraska	100	40
Milwaukee, Wisconsin	99	105
Montclair, New Jersey	100	66
Newton, New Jersey	86	58
New York Inter Urban Water Company	95	78
Passaic, New Jersey	54	72
Providence, Rhode Island	90	68
Rochester and Lake Ontario Water Company	100	94
Utica, New York	98	59
Yonkers, New York	100	96

tuate the caution which must be observed in making reasonable allowance for local characteristics in estimating the probable required consumption for a given community.

An analysis of the distribution of consumption in individual locations will often afford a reasonable explanation for the great variation in per capita consumption. It will be found that the industrial and commercial uses are large in one place, or that the

character of the population in another place is such as to exact a liberal supply of water. In suburban places, large quantities of water are used for lawn sprinkling, more than is generally appreciated.

Progressive Increase in Normal Per Capita Demand

The history of nearly every American city shows that the per capita consumption of water increases as the population increases. In Rochester, New York, where the water department has been conducted along the best lines for years, the per capita consumption increased from 60.2 gallons, in 1879, to 86.6 gallons, in 1907, while during the same period the number of metered services increased from 2 per cent to 70 per cent.

Notwithstanding the efforts which have been made to lessen the quantity of water consumed in Baltimore, the per capita consumption increased from 72 gallons, in 1880, to 120 gallons, in 1909, and this is smaller than in most of the large American cities.

The per capita consumption in the city of Cleveland, in 1874, was 45.36 gallons per day, with 1.28 per cent of the connections in use metered and, in 1908, with 93.61 per cent of the connections metered, the per capita consumption was 100.3 gallons.

These examples may tend to discredit the meter in the minds of laymen. This is not the intention. The City of Cleveland, while illustrating the natural tendency to an increased per capita consumption also illustrates the economy which will result from the introduction of meters. In 1901 the per capita consumption had increased to 169.4 gallons, with 6.42 per cent of service connections metered and the reduction from 169 gallons per capita, represents the saving which resulted from an extended use of meters and proper water waste prevention. Had the per capita consumption continued to increase, as formerly, the present rate would be over 200 gallons per day.

That the presence of meters does exert a marked retarding effect upon the growth of per capita consumption is clearly indicated by the two accompanying diagrams, 3 and 4.

In planning the Boston Metropolitan supply, about fifteen years ago, a very careful investigation was made of the probable requirements of that city, by Mr. Dexter Brackett, now chief engineer, who, at that time, had acquired a large experience in water waste

DIAGRAM NO. 3

FLUCTUATIONS IN THE PER CAPITA USE OF WATER

IN CITIES HAVING LESS THAN 15% OF SERVICES METERED

SMALL FIGURES INDICATE PER CENT OF SERVICES METERED

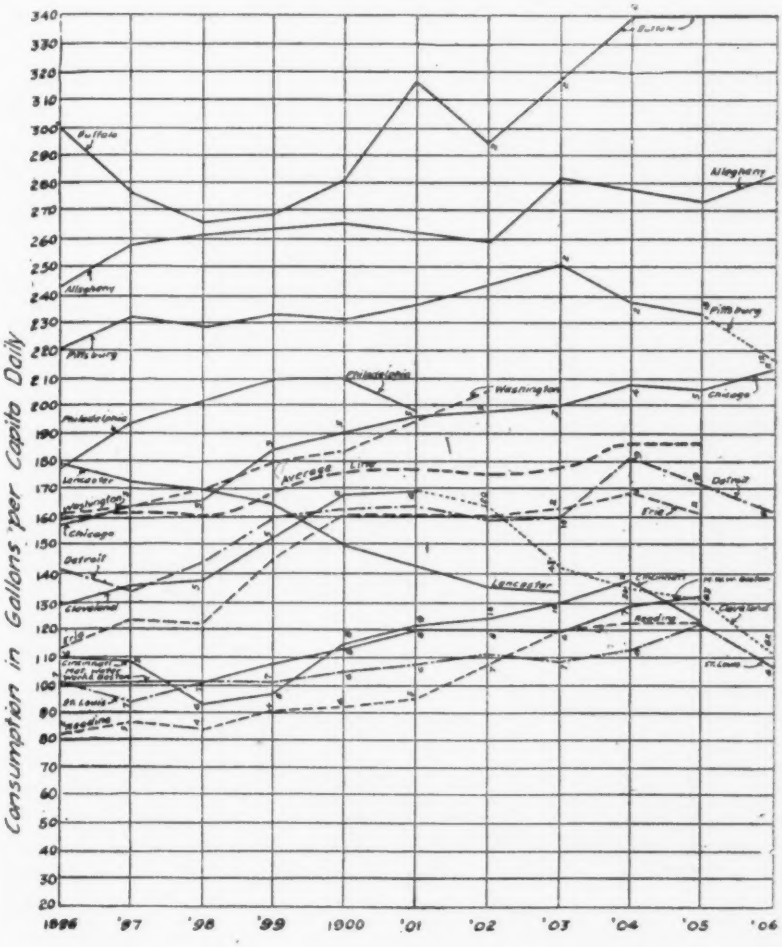
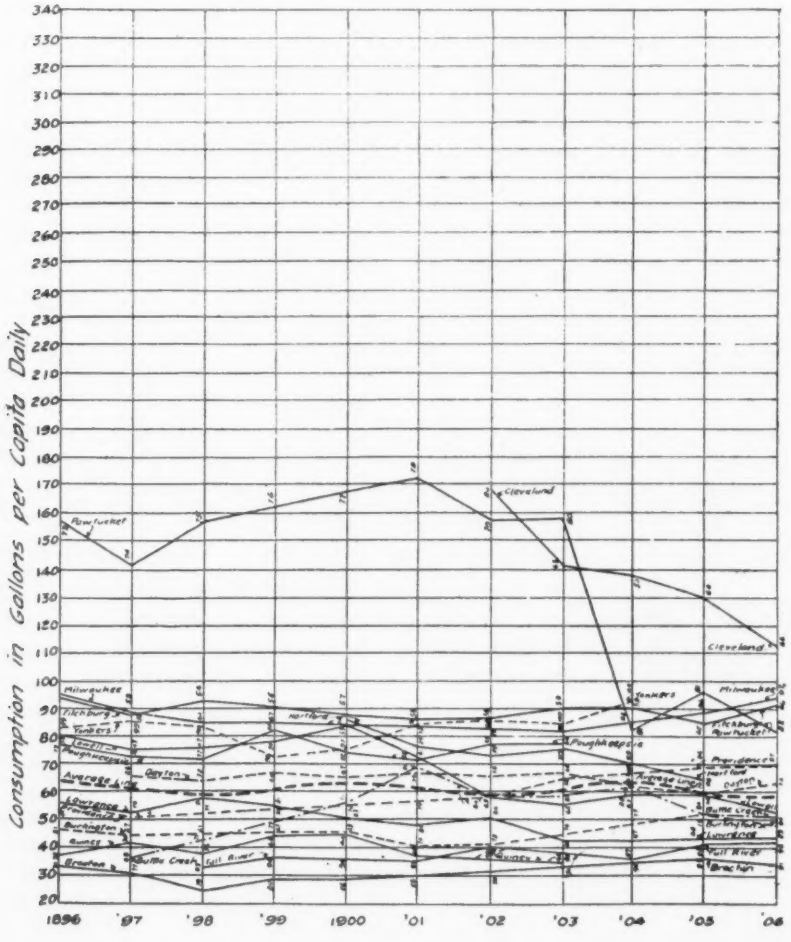


DIAGRAM NO. 4

FLUCTUATIONS IN THE PER CAPITA USE OF WATER

IN CITIES HAVING MORE THAN 50% OF SERVICES METERED

SMALL FIGURES INDICATE PER CENT OF SERVICES METERED



prevention. He estimated the suitable allowance for the Boston Metropolitan District, to be:

	Gallons per Capita
For domestic use	35
For trade and mechanical purposes	35
For public use	5
Waste	25
Total	100

The per capita consumption of water in the Metropolitan District has been as high as 128 gallons per day.

In March, 1906, a careful investigation for the extension and betterment of the Cincinnati Water Works was made by three eminent engineers. After carefully considering the conditions in Cincinnati and other representative cities and assuming that an earnest effort to prevent unnecessary waste would be made at Cincinnati, estimates of the future requirements were based on an average consumption of 130 gallons per capita per day.

The Commission on Additional Water Supply for the City of New York, after reviewing the results of water waste investigations conducted by the writer, decided that the greatest possible saving to be effected by reducing the waste and by decreasing the extravagant use of water, would not provide for more than a few years to come, and based its estimates of the future requirements, which additional works would be called upon to provide, on 150 gallons per day for each member of the population.

In a recent estimate of the probable future requirements of water in Baltimore, made preparatory to plans for a new and additional supply, the engineers decided that it was not prudent to plan new works on the assumption of a smaller per capita use than 130 gallons per capita in 1915; 135 gallons per capita in 1920; 145 gallons per capita in 1930; 150 gallons per capita in 1940.

In estimating probable future demands for water it is advisable where possible to ascertain accurately the amount of water which has been used in the past in the community under consideration, to subdivide the uses of this water as far as possible and, if practicable, to fix upon the probable amount of waste. Then, having determined the total waste, an estimate of waste which would be remediable with the exercise of ordinary care and supervision may be made and the proper correction applied. It is also advisable to check

the local consumption of water with the consumption of towns of like population, location, environment and other characteristics, to see whether the total consumption in the community considered indicates abnormality.

Fluctuations in Consumption

The preceding values for per capita consumption are all averages for the year, and may be exceeded for periods of considerable length.

At the outset of a discussion of the fluctuations in consumption which are noticeable in all water works systems, and must be properly provided for, attention should be called to the fact that differentiation must be made between the fluctuations which occur in a metered and in an unmetered system. The presence of meters introduces a marked levelling effect upon the fluctuations which occur from various causes and, therefore, their presence has a decided effect on the reduction of the peak loads which must be met by a distribution system in an unmetered city. The saving in fixed investment in distribution system due to this levelling effect is not generally appreciated, but must be borne in mind if the best economy is to be obtained in the design.

It is exceedingly difficult to apply the fluctuations which occur in one community to another community, and as portable instruments, such as the pitometer, which are inexpensive and easy to use, are available, actual measurements of the fluctuations to be met in a given place should be made prior to the re-design of a distribution system, where the data available are not sufficient for the purposes at hand.

The daily consumption will frequently be considerably higher than the average during cold winter months due to the opening of bibb cocks to prevent freezing in the mains and service connections. It will frequently be higher than the average in the summer due to lawn and street sprinkling and to the more liberal use of water for bathing purposes. It will be affected, though in a smaller degree, by less marked fluctuations in the temperature of the air, and the amount of rainfall during the summer will produce its effect.

The daily consumption in some communities will be much higher on Mondays and Tuesdays when domestic washing is being done than on Saturdays and Sundays.

The consumption will be much higher during the day than at

night, and will ordinarily, for obvious reasons be much higher for a few hours in the morning and late afternoon than during other hours in the day. These variations will be less marked in large communities than in small ones.

As an illustration of the fluctuations which may occur, Diagrams Nos. 5 to 11 are presented herewith which indicate the existence and extent of these variations in the places to which they apply. The figures presented by the diagrams show the fluctuations in total consumption including that used for commercial, industrial, railroad and other purposes.

Diagram No. 5 gives the variations in the average daily consumption by months in a city of 250,000 people during the year 1907 and the first four months of 1908. It will be noted that the consumption is highest in February in each year, the daily consumption in February, 1907, being 1.08 times the average daily consumption for the year.

Diagram No. 6 gives the variations in the average daily consumption by months from July, 1908, to December, 1912, inclusive in a community in which the population increased from 20,645 to 31,410 during the period covered by the record. In this community, whose average population during the period was approximately 25,000 people, the consumption is highest in July of each year, the daily consumption during July being from 1.12 to 1.20 times the average daily consumption for the year. On this diagram is also noted the consumption during the absolute maximum day of each year. In all but one instance, this maximum day occurs during the maximum one month, and varies from 1.5 to 1.95 times the average daily consumption for the year.

Diagram No. 7 shows the hourly fluctuations in consumption as measured by pitometer in a community of 5,000 people. The record, covering several days, also illustrates well the variations in the daily consumption on different days of the week. It shows an hourly rate of consumption varying from 0.35 to 1.86 times the average rate during the day on which the maximum hour as shown occurred.

Diagrams Nos. 8 to 11, inclusive, show the annual, monthly, daily, and hourly variations in consumption at Auburn, New York, which has about 9 per cent of the service taps metered.

Diagram No. 8 shows the monthly variations in the total average daily consumption from 1892 to 1912 inclusive, also the progressive

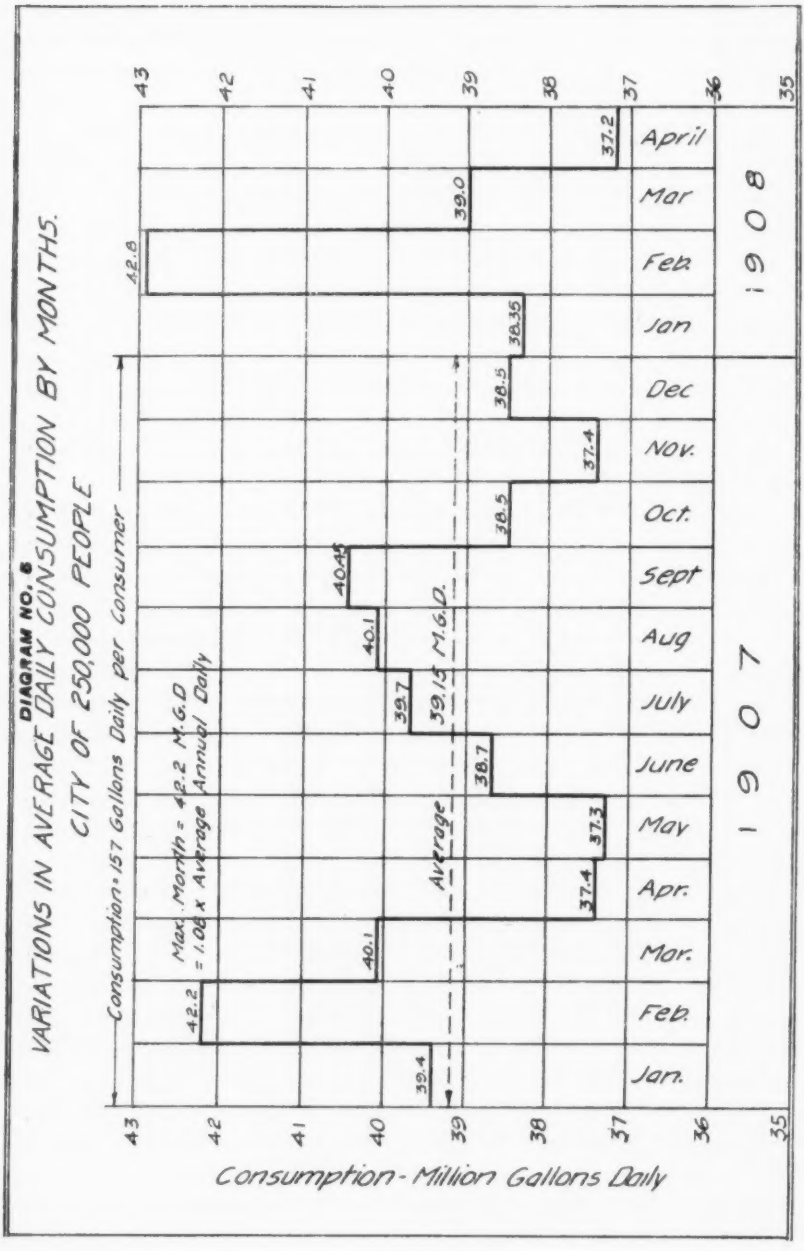


DIAGRAM NO. 6
VARIATIONS IN AVERAGE DAILY CONSUMPTION BY MONTHS.
CITY OF 250,000 PEOPLE
Consumption - 157 Gallons Daily per Consumer
Max. Month = 42.2 M.G.D
= 1.08 x Average Annual Daily
Average
39.15 M.G.D.
42.2
39.4
40.1
37.4
37.3
38.7
39.7
40.1
40.45
38.5
37.4
38.5
38.35
42.8
39.0
37.2
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug
Sept
Oct.
Nov.
Dec
Jan
Feb
Mar
April
1907
1908
43
42
41
40
39
38
37
36
35
Consumption - Million Gallons Daily

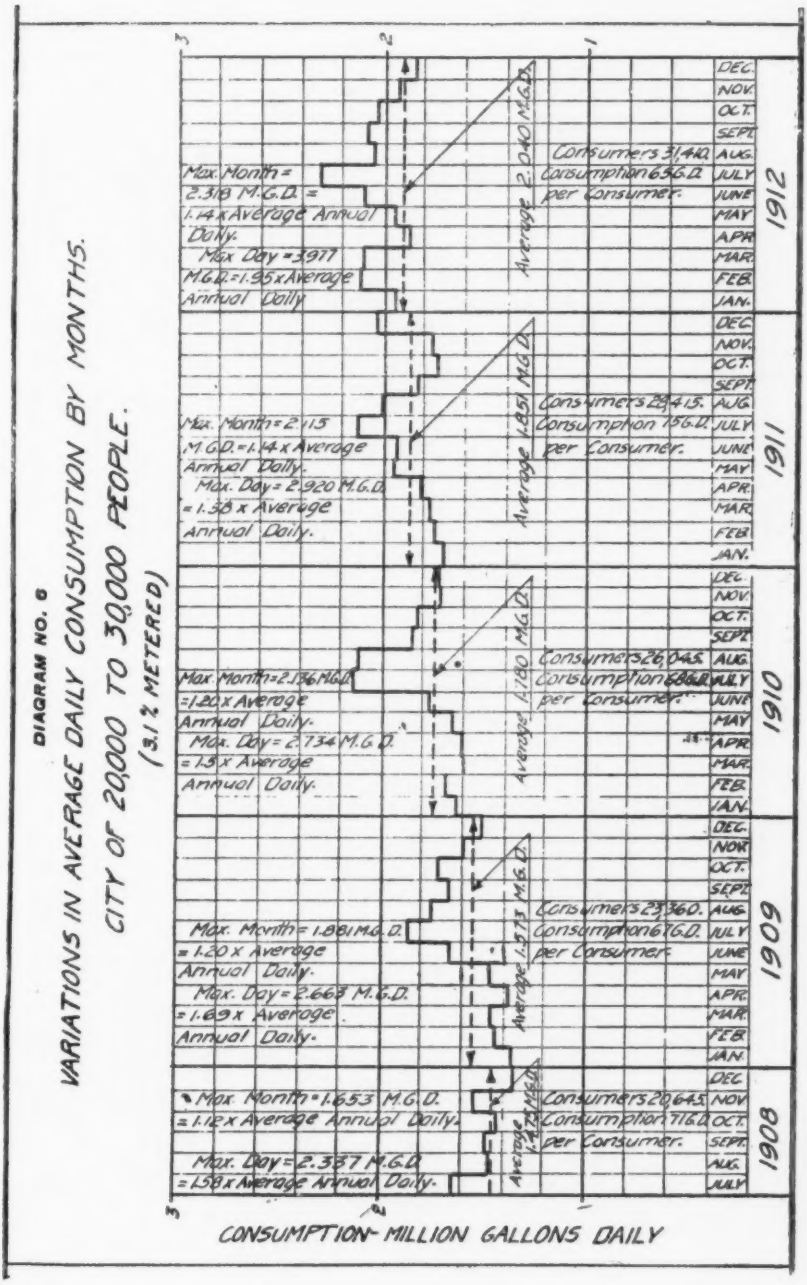


DIAGRAM NO. 6
VARIATIONS IN AVERAGE DAILY CONSUMPTION BY MONTHS.
CITY OF 20,000 TO 30,000 PEOPLE.
(3.1 % METERED)
Max. Month = 2.318 M.G.D. = 1.14 x Average Annual Daily.
Max Day = 3.917 M.G.D. = 1.95 x Average Annual Daily
Average 2.040 M.G.D.
Consumers 31,442
Consumption 65 G.D. per Consumer.
1912
Max. Month = 2.115 M.G.D. = 1.4 x Average Annual Daily.
Max. Day = 2.920 M.G.D. = 1.38 x Average Annual Daily.
Average 1.851 M.G.D.
Consumers 29,415.
Consumption 75 G.D. per Consumer.
1911
Max. Month = 2.136 M.G.D. = 1.20 x Average Annual Daily.
Max. Day = 2.734 M.G.D. = 1.5 x Average Annual Daily.
Average 1.780 M.G.D.
Consumers 26,045.
Consumption 82 G.D. per Consumer.
1910
Max. Month = 1.881 M.G.D. = 1.20 x Average Annual Daily.
Max. Day = 2.663 M.G.D. = 1.69 x Average Annual Daily.
Average 1.573 M.G.D.
Consumers 23,360.
Consumption 67 G.D. per Consumer.
1909
Max. Month = 1.653 M.G.D. = 1.12 x Average Annual Daily.
Max. Day = 2.387 M.G.D. = 1.58 x Average Annual Daily.
Average 1.474 M.G.D.
Consumers 20,645.
Consumption 71 G.D. per Consumer.
1908
DEC. NOV. OCT. SEPT. AUG. JULY JUNE MAY APR. MAR. FEB. JAN.
CONSUMPTION - MILLION GALLONS DAILY

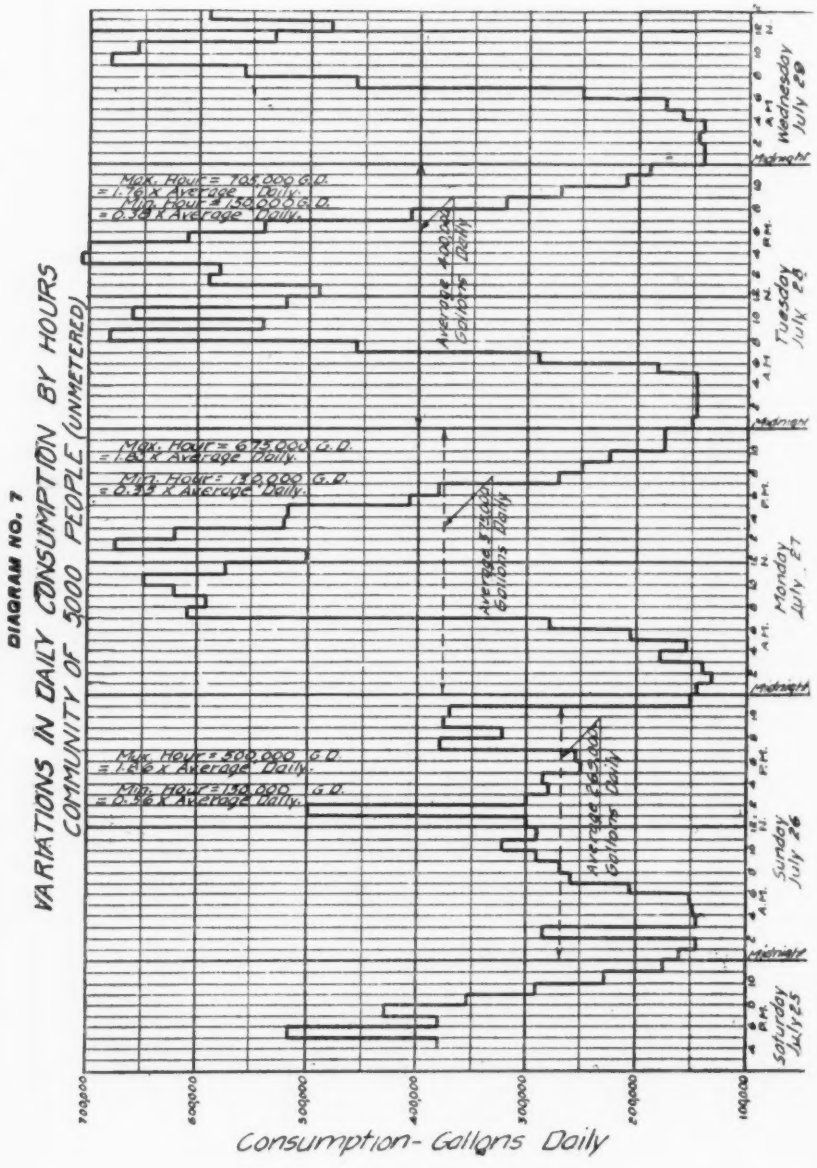


DIAGRAM NO. 7
VARIATIONS IN DAILY CONSUMPTION BY HOURS
COMMUNITY OF 3000 PEOPLE (UNMETERED)
Max. Hour = 705,000 G.D.
= 1.76 x Average Daily.
Min. Hour = 150,000 G.D.
= 0.38 x Average Daily.
Average 400,000 Gallons Daily
Max. Hour = 675,000 G.D.
= 1.69 x Average Daily.
Min. Hour = 132,000 G.D.
= 0.33 x Average Daily.
Average 399,000 Gallons Daily
Max. Hour = 500,000 G.D.
= 1.19 x Average Daily.
Min. Hour = 130,000 G.D.
= 0.31 x Average Daily.
Average 663,000 Gallons Daily
Midnight
A.M.
P.M.
Saturday July 25
Sunday July 26
Monday July 27
Tuesday July 28
Wednesday July 29
700,000
600,000
500,000
400,000
300,000
200,000
100,000
Consumption - Gallons Daily

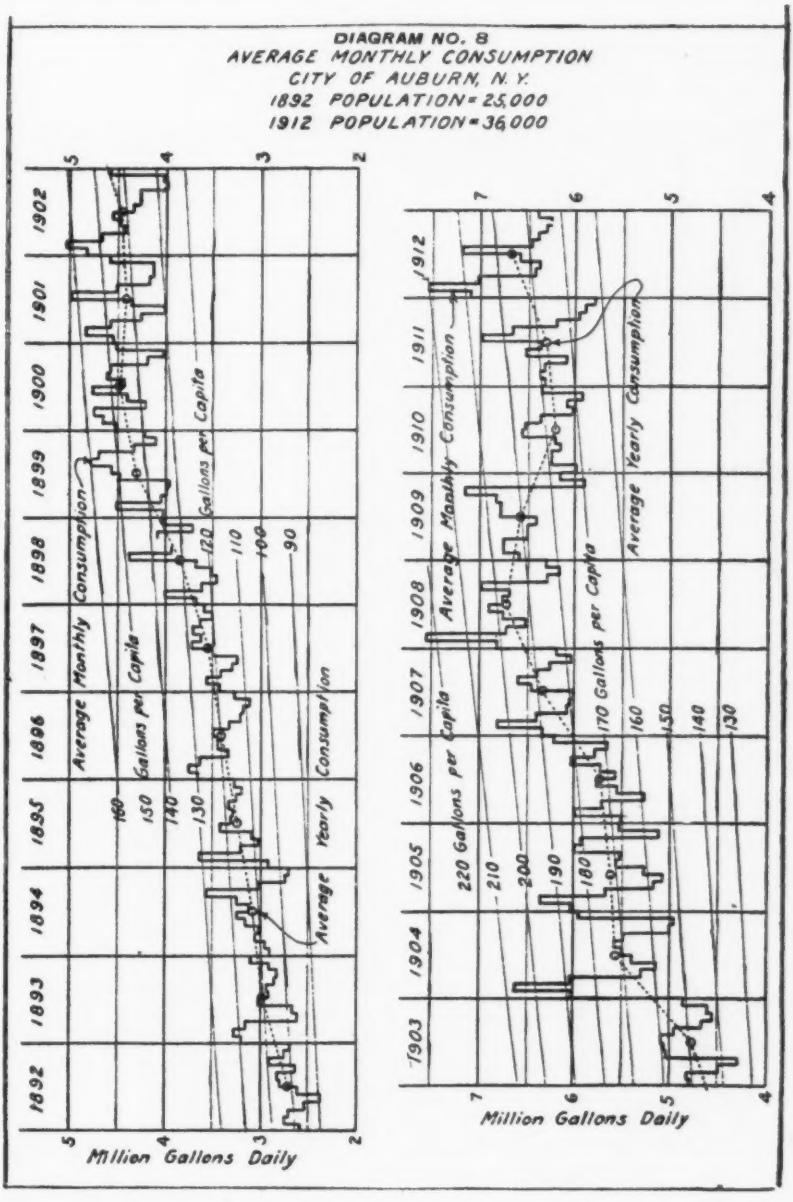


DIAGRAM NO. 8
AVERAGE MONTHLY CONSUMPTION
CITY OF AUBURN, N.Y.
1892 POPULATION = 25,000
1912 POPULATION = 36,000
Average Monthly Consumption
Gallons per Capita
Average Yearly Consumption
Million Gallons Daily
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912

DIAGRAM NO. 9

AVERAGE DAILY CONSUMPTION OF WATER
RAINFALL AND TEMPERATURE OF AIR
CITY OF AUBURN, N.Y.
1912 – POPULATION = 36,000

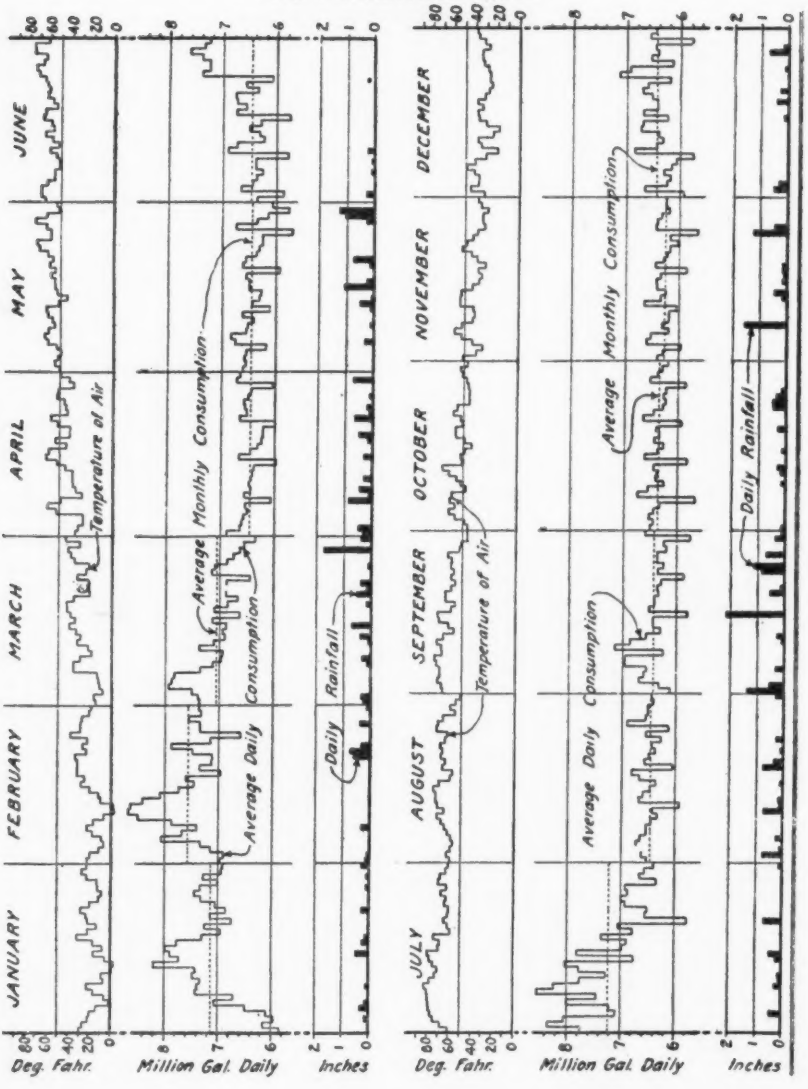


DIAGRAM NO. 10

HOURLY VARIATION IN COLD WEATHER CONSUMPTION
CITY OF AUBURN, N.Y.
1912 POPULATION 36,000.

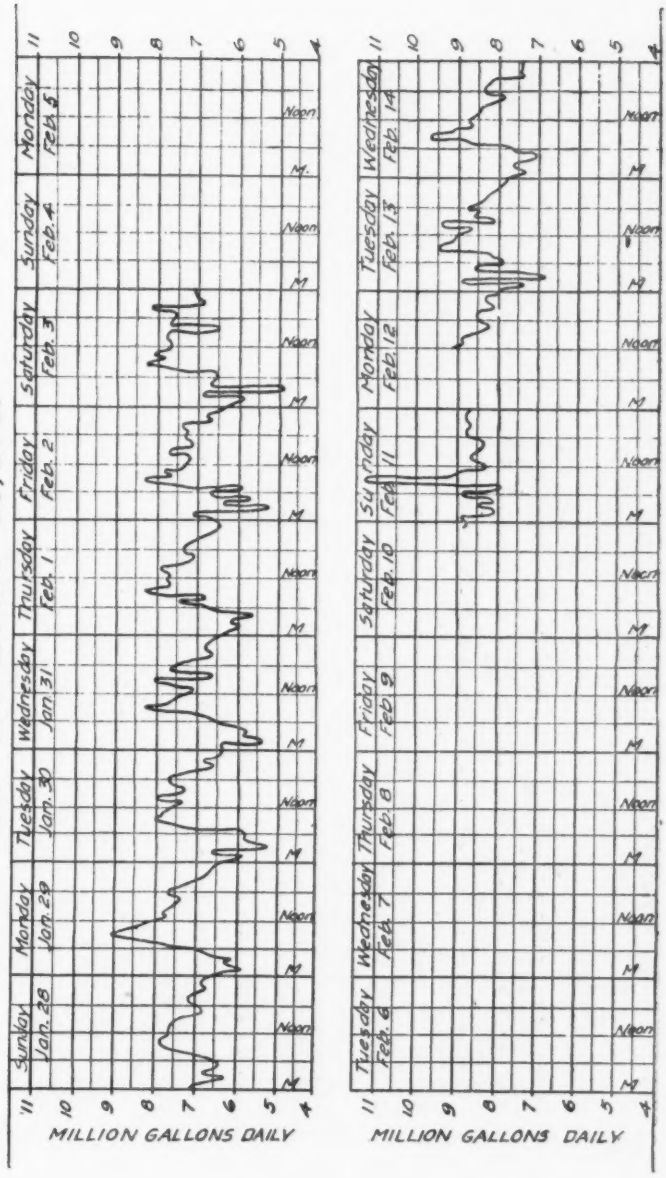
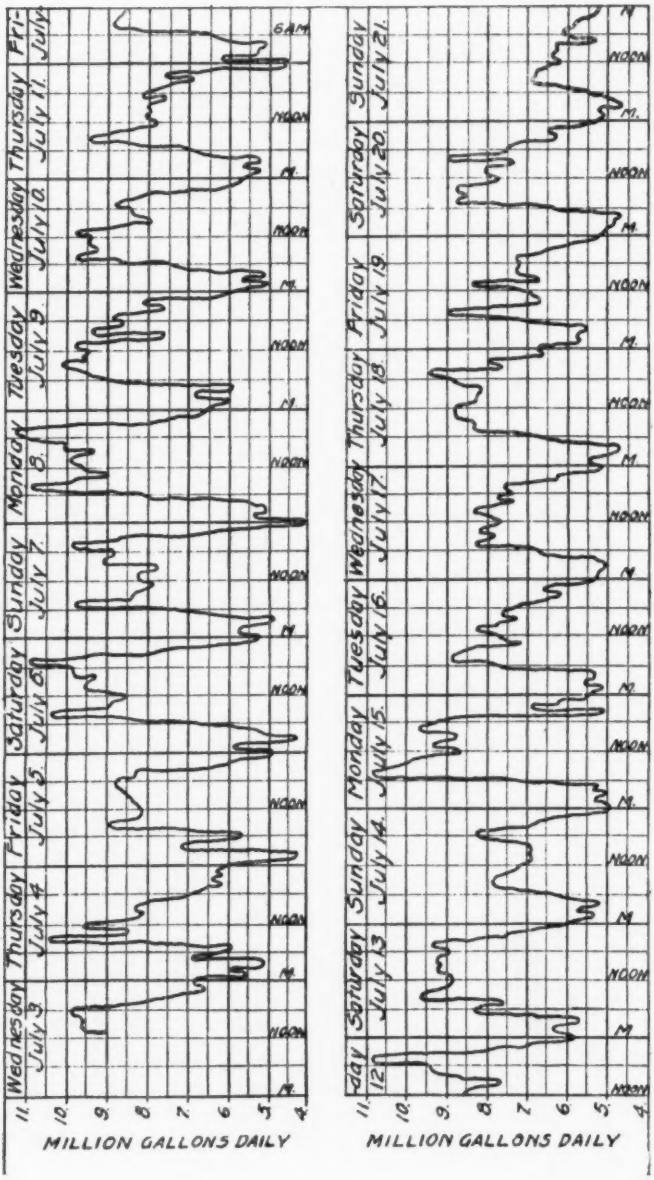


DIAGRAM NO. 11

HOURLY VARIATION IN WARM WEATHER CONSUMPTION

CITY OF AUBURN, N.Y.

1912 POPULATION 36,000.



increase in total and per capita consumption during the period covered by the record. The population during this interval increased from about 25,000 to approximately 36,000 people.

Diagram No. 9 gives the daily fluctuations in consumption for each month of the year 1912, together with the corresponding average daily rainfall and air temperature.

Diagram No. 10 indicates the hourly variations in cold weather consumption from Sunday, January 28, to Saturday, February 3, 1912, inclusive, and from Sunday, February 11 to Wednesday, February 14, 1912, inclusive.

Diagram No. 11 shows the hourly variations in hot weather consumption from Wednesday, July 3, to Sunday, July 21, 1912, inclusive.

These data, all relating to the same community, are interesting and illuminating.

In the twenty-one years covered by the record, the total average daily consumption per capita increased from 100 gallons in 1892 to practically 200 gallons in 1908. The value in 1912 was 188 gallons daily per capita.

A clear relationship is observable on Diagram No. 9 between the average daily consumption and temperatures which are much above or much below the normal. It is also possible to trace in a general way a relationship between the curve of average daily consumption and the daily rainfall as recorded on the same sheet. In July, August, September, for example, there are numerous days on which a heavy precipitation was accompanied or immediately followed by a large drop in the daily consumption.

February was the month of highest consumption in nine out of twenty-one years, July being the highest month during six of the remaining twelve years. The average daily consumption during the highest one month varied from 1.02 to 1.18 times the average daily consumption for the corresponding year. It averaged 1.11 times the latter value. In the year 1912 the day of maximum consumption occurred on February 10, the month of maximum consumption, and amounted to 1.31 times the average daily for the year. On July 8 of the same year the average daily consumption amounted to 1.28 times the average daily for the year.

The hour of greatest hot weather consumption in 1912 occurred about 7 p.m. of July 8, the day of highest hot weather consumption. It amounted to 1.68 times the average annual daily rate.

The hour of greatest recorded cold weather consumption occurred at about 9 a.m., February 11, the morning following the day of highest cold weather consumption. It then amounted to 1.69 times the average annual daily rate, practically the same as the maximum hourly hot weather consumption. In general, higher hourly maxima and lower hourly minima were recorded during the month of July than during the month of February.

For purposes of distribution system design it will not usually be necessary to provide carrying capacity for a quantity greater than the estimated average daily demand during the maximum one week of the period considered, in addition to the fire service requirements. The worst that can happen as a result of failure to design the mains for the occurrence of the maximum fire service requirements coincident with the maximum daily or hourly demand for water for all other purposes, will be a slight reduction in the fire pressures below those which the system is designed to give. Any well designed distribution system is sufficiently flexible to carry overloads for short periods with no other effect than a slight reduction in the maximum fire service pressure.

At all ordinary times, and even during times of moderate sized fires, mains which have been designed to carry the quantities required to satisfy the maximum demands during a conflagration in the maximum week of the maximum year will have ample capacity to deliver the maximum daily and hourly demands without appreciable loss of pressure.

It may also be remarked in this connection that there is a normal tendency to a reduction in the volume of water required for purposes other than fire during the occurrence of an exceptionally large fire, and, finally, it may be said, that the probability of a conflagration occurring coincidentally with the maximum daily or hourly flow in a maximum year is so remote that it would not be commercially expedient to provide for it.

Abnormal Fluctuations in Consumption

In addition to the normal hourly, daily and seasonal fluctuations in the quantity of water required, every water works plant is subject to more or less sudden, violent and abnormal fluctuations in demand. This is particularly true of small installations, though these sudden demands must not be lost sight of even with larger

plants, as they materially affect the size of mains required to give adequate service under all conditions.

Although many kinds of industrial service entail sudden demands for large quantities of water which must be given special study in order that they may be met without crippling the service, the chief cause of these sudden and violent fluctuations is the fire service requirement.

In a plant supplying on the average 1,000,000 gallons per day, which is equivalent to approximately 700 gallons per minute, it may be necessary to supply on short notice eight or ten fire streams delivering 250 gallons per minute each, a total of from 2,000 to 2,500 gallons per minute, or from three to four times the normal delivery. This delivery must be met without undue loss of pressure if the fire service is to be effective, and it is necessary in designing a distribution system to make provision for these sudden and excessive demands.

Fire Service Requirements

A number of rules and formulae have been deduced for estimating the quantity of water necessary to afford proper fire protection in communities of different size. No one of these formulae is of universal application, and, for the most part, they give results considerably in excess of the values which actually obtain generally in the United States.

Table No. 9 gives a few of these formulae.

The National Board of Fire Underwriters does not estimate the number of fire streams required in the congested value districts in cities of different size by formulae, but has determined the number which it considers adequate in a large number of American cities from a special investigation of the conditions in each place. The formula given as that of the underwriters is the equation of a curve representing the average of the published requirements for the cities investigated and reported upon by this Board from 1905 to 1911, classified according to size. See paper "Reasonable Return for Fire Hydrant Service" by Metcalf, Kuichling and Hawley, *Proceedings of the American Water Works Association*, 1911.

That there is no fixed relation between population and the maximum number of fire streams required for adequate fire protection is indicated by a study of the individual points from which this equation was deduced. There is, for example, one instance in which

the Board estimates that 10,000 gallons per minute, equal to forty simultaneous fire streams of 250 gallons per minute each, under a flowing pressure of 75 pounds at the hydrant, is necessary for the proper protection of a city of 52,000 people and another instance in which this amount is deemed adequate for a city of 360,000 people.

TABLE NO. 9

Quantity of water, and number of fire streams required for fire service by various formulae

	John R. Freeman (1892)		Allen Hazen Emil Kuichling (1897)	National Board of Fire Underwriters (1910)
	Maximum	Minimum		
(1)	(2)	(3)	(4)	(5)
Formula giving total quantity of water in gallons per minute required for fire protection service in American towns and cities, at 250 gallons per fire stream per minute	$Q = 250Y$	$Q = 25Y$	$Q = 250Y$	$Q = 1020\sqrt{X} \times (1 - 0.01\sqrt{X})$
Formula giving total number of fire streams of 250 gallons per minute each, required for fire protection service in American towns and cities	$Y = \frac{X}{5} + 10$	$Y = 1.7\sqrt{X} + 0.03\ X$	$Y = 2.8\ \sqrt{X}$	$Y = \frac{Q}{250}$

X = Number of thousands of inhabitants.
Y = Total number of fire streams required.
Q = Total quantity of water required, gallons per minute.

The wealth per capita, character and location of hazards, and other individual characteristics unrelated to the population of a city, are material factors in the determination of what constitutes satisfactory fire protection. Formulae should, therefore, be used with great caution, in the determination of the number of fire streams required, and individual judgment founded upon local inspection should control.

Subdivision of Water Consumption by Districts

The present and future domestic and public consumption of water in each ward may be assumed to be proportional to the present and estimated future ward population. In some instances, the

accuracy of this assumption may be modified by the fact that certain wards may be supplied in part from local sources, or that most of the non-consumers are located in one or a few wards. Also, difference in the character of the population may increase or diminish the per capita consumption in different wards, but with a knowledge of local conditions and with the exercise of proper judgment, the estimates of the ward consumption may be modified accordingly, if such modifications are deemed necessary.

In considering methods for the proper subdivision of the demands in local areas, it must be borne in mind always that there are so many variables in the supply and distribution of water that it is not possible to figure exact quantities. As is the case in the design of sewers, the distribution system must have a certain factor of safety. Also, owing to the flexibility of a distribution system, particularly where it is reinforced by a great number of smaller pipes forming what might be termed a subsidiary distribution system, deviations in the center of supply from those assumed have but small effect on the usefulness of the system. Moreover, the only effect of a more rapid increase in a certain locality than was anticipated will be a slightly reduced pressure or a shortening of the useful life of the system as planned with the concomitant necessity for reinforcements.

PRESSURES

Service Pressures Required

Following the determination of the immediate and probable future demands for water comes the question of the pressure under which this water should be delivered. If there were no draft of water from the mains, the pressure throughout the system would be that ordinarily termed "static pressure," or the pressure resulting from the elevation of the water in a reservoir. A draft of water from the mains, however, immediately sets in motion the mass of water therein contained, causing friction which is proportional to the draft, and which must be overcome. The dynamic or service pressures at various points on the system may be greater or less than the corresponding static pressure. When the supply is from a reservoir, the service pressure at any point on the distribution system will be less than the corresponding static pressure by the amount of the friction loss between the reservoir and the point considered. When water in excess of the immediate requirements is flowing from a

pumping station into a storage or distributing reservoir, the dynamic pressure at all points between the pumping station and the reservoir will be greater than the corresponding static pressure from the reservoir.

When fire service is furnished directly from the mains, service pressures of not less than 70 to 75 pounds at the hydrant under conditions of maximum draft should be maintained in the congested

TABLE NO. 10

Discharge of 1⅛-inch smooth hose nozzles Hydrant pressure required—Height and distance of jet

	INDICATED PRESSURE BY GAUGE ATTACHED AT BASE OF PLAY PIPE AND SET LEVEL WITH END OF NOZZLE	EXTREME HEIGHT OF JET		EXTREME HORIZONTAL DISTANCE REACHED BY JET		GALLONS PER MINUTE DISCHARGED	POUNDS PRESSURE REQUIRED AT HYDRANT (OR STEAMER) WHILE STREAM IS FLOWING TO MAINTAIN PRESSURE AT BASE OF PLAY PIPE, AS PER FIRST COLUMN, TROUGH VARIOUS LENGTHS OF 2½ INCH ORDINARY BEST QUALITY RUBBER LINED HOSE—INSIDE SMOOTH				
		Average of highest drops, vertical jet, still air	Maximum limit of height as good effective fire stream with moderate wind	Average extreme drops at level of nozzle with still air	Maximum limit of distance as good effective fire stream with moderate wind		50 ft. length	100 ft. length	200 ft. length	300 ft. length	400 ft. length
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	lbs.	*ft.*	*ft.*	*ft.*	*ft.*		*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Feeble streams	5	11		19		84	6	7	9	10	12
	10	22	18	39	22	119	12	14	17	20	24
	15	32	27	59	31	146	19	21	26	31	35
	20	43	36	80	38	168	25	28	34	41	47
Ordinary fire streams — Fair	25	54	44	99	44	188	31	35	43	51	59
	30	64	52	115	50	206	37	42	52	61	71
Ordinary fire streams — Good	35	74	59	130	54	222	43	49	60	71	82
	40	84	65	142	59	238	50	56	69	81	94
	45	94	70	152	63	252	56	63	77	92	106
Ordinary fire streams — Excellent	50	104	75	162	66	266	62	70	86	102	118
	55	113	80	170	69	279	68	77	95	112	130
	60	122	83	178	72	291	74	84	103	122	141
Unusually strong streams	65	130	86	185	75	303	81	91	112	132	153
	70	136	88	191	77	314	87	98	120	143	165
	75	142	90	197	79	325	93	105	129	153	177
	80	146	92	203	81	336	99	112	138	163	188
	85	150	94	209	83	346	106	119	146	173	200
	90	153	96	214	85	356	112	126	155	183	212
	95	156	98	219	87	366	118	133	163	194	224
	100	158	99	224	89	376	124	140	172	204	236

value districts, although 50 to 60 pounds minimum will usually suffice for residential sections. With these pressures, fire streams throwing from 200 to 250 gallons per minute through $1\frac{1}{8}$ inch smooth nozzles attached to 200 feet of $2\frac{1}{2}$-inch ordinary, best quality, rubber lined hose may be obtained, as will be seen from Table No. 10. The data there presented are taken from the monograph *Fire Stream Tables* published by the Associated Factory Mutual Fire Insurance Companies, and based upon experiments conducted by John R. Freeman in 1888.

Even with service pressures of 70 to 75 pounds in the congested value districts, it may be necessary, in order to insure the proper protection of modern buildings of great height, either to equip and maintain one or two fire engines, the number depending upon the character and size of the district, and of the buildings located therein, or to require that the property owners install and maintain underwriters' pumps to boost the fire pressure on the distribution mains. For all ordinary towns and cities, however, 70 to 75 pounds at the hydrant will give adequate fire service without the necessity for the use of portable fire engines.

Where fire engines are used, a service pressure of 30 pounds minimum on the mains will usually be ample in residential sections, as this pressure will insure the delivery of water to the fourth story of an ordinary building. With this minimum service pressure some of the higher buildings, such as hotels and apartment houses, may be obliged to install local pumping plants to raise the water for distribution in the higher stories, but in view of the expense of maintaining high pressures for ordinary distribution it is but just that this cost should be borne by the parties benefiting, rather than by the general public.

Number of Service Pressure Districts

In considering the question of pressures, the designer should weigh thoroughly the relative economy of creating more than one service pressure district in cities where there are large differences in ground elevation. If these differences are marked, it may be necessary to create two or more entirely distinct service pressure districts in order that the required pressure at high elevations may not produce undesirably high pressures in the low lying areas. When this is done, the design of the distribution system in each service district may become a problem complete in itself, as, for example,

in the case where each service district is supplied from a separate source, or the systems may be inter-related and inter-dependent, as in a situation where the feeder mains of one service pressure district must be of sufficient size to carry the water consumed in one or more of the others. Take, for example, the case where water for an entire city is delivered to the highest district, and thence through pressure reducing valves to the pipes in the lower districts. Another case would be when the water is pumped through the supply mains of a low pressure district before being repumped to the high service mains. Even when the differences in ground elevation are not excessive, it may be advisable to create more than one service pressure district in the case of pumped supplies, thus reducing the pressure at the pumps, and, therefore, the cost of pumping.

Static pressure

Having decided upon the service pressures required at various critical points of a system, and the number of service pressure districts into which the city will be divided, the next step is to determine the size of mains required to convey the estimated quantities of water at the required pressures from the immediate source to the various points of use. This source may be a pumping station, distributing reservoir, or the point at which a conduit or supply main delivers to the distribution system.

The problem presented may involve fixed pressures at the immediate source, as, for example, where one has to deal with existing pumping plants, distributing reservoirs, or conduit lines, the elevation of or pressure from which is fixed. Under these circumstances, the sizes of the distributing mains must be figured so that the losses in friction between the immediate source and the points of use shall not exceed the difference in pressures at the two points.

The problem presented may be one in which the initial pressures are not fixed, and where the designer may, at his discretion, determine upon the most economical pressures to be carried at the immediate source. He is then at liberty to adjust pressures and pipe sizes in the distribution system so as to increase or diminish the friction losses therethrough in such ways as economic considerations may suggest.

The problem presented is really the determination of the static pressures required to produce most economically the desired serv-

ice pressures, or the determination of the most practical static pressure to be used. The most advantageous static pressure will be that at which the total annual cost of supplying satisfactory service is a minimum.

Below are listed the principal elements in the construction or operation of a water works plant which will increase or decrease with an increase in pressure carried. The effect of these several elements upon the total annual cost of supplying water must be appraised by the designer and carefully weighed and compared under the various static heads considered, preparatory to a final decision.

Elements in the design or operation which will increase with an increase in static pressure—other things being equal.

1. Cost of pipes composing the distribution system, excluding feeder mains.
2. Weight and strength of house service connections and plumbing fixtures.
3. Cost of service pumping engines.
4. Cost of boilers, stacks, and pumping station auxiliaries.
5. Cost of fuel per million gallons pumped.
6. Cost of repairs to mains in distribution system.
7. Cost of repairs to house service connections and plumbing.
8. Cost of water wasted through leaks in distribution system.
9. Cost of water wasted through house service connections and leaky plumbing fixtures.
10. Quantity of water used per consumer.

Elements in the design or operation which will decrease with increase in static pressure—other things being equal.

11. Cost of pipes composing the feeder mains.
12. Diameter of house service connections.
13. Number and capacity of booster plants required to increase pressures in restricted high areas.

Some of the elements listed above appear at first sight to exert an appreciable influence on the cost of the plant. Analysis, however, will show that a number of them may be discarded from serious consideration.

Generally, the experienced engineer will be able to weigh the relative effect upon the cost of the several considerations affecting the selection of the most advantageous static head, without elaborate calculations of the relative economy of several schemes.

In addition to the effect exerted upon the cost by the elements mentioned above, the cost may be affected by external considerations, characteristic of the particular community considered, such as the greater land values of the reservoir sites at low elevations, or

vice versa, topographical considerations which would make the cost of a reservoir at one elevation more costly than one at some other level, or the existence of expensive structures which it would be commercially inexpedient to discard.

Having now discussed generally the various external features affecting the design of a pipe distribution system, we come to the specific consideration of the system itself.

The function of a pipe distribution system is the conveyance of water from the point at which the water is delivered to a community to the point at which it is to be used. This delivery must be accomplished in such a manner that an uninterrupted and adequate supply of water under satisfactory pressure will be available at every point on the system under all conditions of demand. The supply must be sufficient in respect of pressure and volume not only to meet the present and future demands of ordinary domestic and public consumption, but to supply the needs of large industrial consumers and for the extinguishment of fires. It must be able to meet not only the *average* present and future demands of these several classes of consumers, but such of their maxima as are likely to occur simultaneously. The pipes should be of a size sufficient to supply these maxima after proper allowance has been made for deterioration in the carrying capacity of the mains as a result of tuberculation and from other causes.

The delivery of water must be accomplished at a cost as low as is consistent with a wise provision for the future growth of the community to be served. By low cost is meant not necessarily the first cost, but the total annual cost including fixed charges, depreciation, replacements, maintenance and incidental costs chargeable to poor construction, such as losses of water through leakage, etc.

The actual design of a distribution system including a detailed analysis of the effect of various elements herein discussed upon the cost thereof will be left for another paper.

DISCUSSION

MR. JOHN W. ALVORD: Mr. Hill has gone very carefully into a very important matter when he points out the large investment made in our distribution systems and the usually scant attention given to the design, care and enlargement.

It is a matter of common knowledge to those of us who investigate a great many plants that many of them are deficient in distribution capacity, and that this condition is usually caused by the growth of the community, the large investment involved, and the economies demanded by the different administrations of the city government from year to year. These influences cause the distribution system to pass into inefficiency almost insensibly. Without a thorough and general over-hauling at stated intervals, this often results in a public calamity and unquestionably a great deal of good can be done by having a careful study of distribution systems made and plans outlined for enlargement and growth, once in a given number of years, depending on the growth of the city. The speaker would point out, however, that the proper capacity of a distribution system design rests almost wholly on the fire protection requirements. It must be designed for the fire protection and when so designed is usually ample for all other purposes. This fact simplifies greatly the questions which must be studied with reference to it. There is, however, a great deal of data which can be gathered and studied both with reference to the present and the future needs along the lines of fire protection. It would certainly be very profitable if studies of this kind could be more often made.

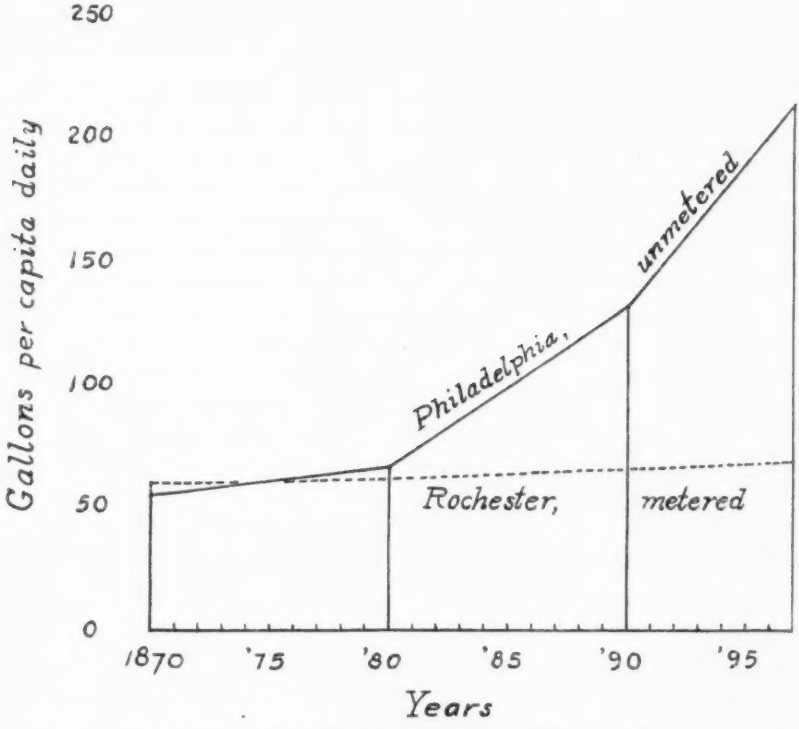
MR. JOHN C. TRAUTWINE, JR.: Mr. Hill has mentioned the case of Rochester, N. Y., where, forty years ago, with less than 2 per cent of the taps metered, the consumption was less than it is today with nearly all the supplies metered; but Mr. Hill, the speaker is sure, would not wish to cite this case as arguing inefficiency of the meter as a waste-restricter.

The object of metering should be to restrict waste, not to discourage legitimate use; and, as the case of Rochester shows, legitimate use properly increases as we advance in civilization and in culture.

Hence, in order to estimate the value of the meter in Rochester, we must compare the present consumption, with nearly all supplies metered, not with the consumption of forty years ago, but with *what the consumption might now be* if meters had not been generally applied.

And, if it be objected that we have no data as to what the Rochester consumption might now be, without meters, the speaker sug-

gests, for comparison, his own unhappy city of Philadelphia. Here, although the city charter leaves such questions to the department of public works, they are really settled, in defiance of the charter, by the ignorant populace and by its representatives in the City Councils; and the water meter is still practically unknown.



INCREASE IN DAILY PER CAPITA WATER CONSUMPTION.
ROCHESTER, N. Y., METERED.
PHILADELPHIA, UNMETERED.

Forty years ago, our (unmetered) consumption was about the same as that of then still unmetered Rochester; but, during the forty years, while Rochester, steadily increasing its use of meters, has kept its consumption down to a figure but little greater than that of forty years ago, Philadelphia's consumption, still practically unmetered, has quadrupled.

The nature of the comparison is indicated by the accompanying sketch, drawn roughly to scale.

Mr. Hill mentioned, incidentally, some of the disadvantages under which small communities labor by reason of their smallness and of their consequent lack of means. For instance, while a large city can well afford to engage the services of a commission composed of the highest-paid engineers of the country, the small town must be content with talent of a lower order, if indeed it does not force its problems of extension, etc., upon its already overworked and underpaid superintendent.

Now this consideration, which affects all the relations of the small town, often compelling it to false economies in all directions, emboldens the speaker to venture the prediction that, fifty years from now, all the municipal water supplies of the country will be administered from Washington, or from wherever the national capital may then be, and that, a hundred years from now, all the water supplies of the world will be administered from the world capital. If this sounds chimerical, the speaker asks you to remember that our always progressive Massachusetts friends have already made a notable move in this very direction, in the creation of their Metropolitan Water and Sewerage Board, which administers the supply not only of Boston City, but that of adjacent communities, which, formerly, had their separate supplies.

In Italy also, the national government is constructing a gigantic supply, carrying spring water through the Apennines, at a total cost of some $30,000,000, for the supply of the arid district of Puglia, on the opposite side of Italy, with its population of about 3,000,000.[1]

The usual answer to predictions of centralization is that each community knows its own needs and resources better than could a national bureau at Washington; but this is disproven by the two cases just mentioned, and by the fact above cited that the smaller community cannot afford to employ the highest talent; whereas the predicted centralization will give to every community, large or small, the benefit of a large organization of experts, with resident assistants in each community, and with facilities for gathering and using information as superior to those of the present consulting engineer, as those of the United States Weather Bureau are superior to those of any possible private organization of weather experts.

[1] Since writing as above, the writer has received, from the American Society of Civil Engineers, a circular from its special committee "on a National Water Law."

And, even if each community best knew its own problems, it need scarcely be mentioned that it has not the nation's power of physically solving those problems; and it must be borne in mind that, in the next fifty years, we, or our successors, will have attained to a far livelier realization than at present of the fact that the health and wealth of the whole are dependent upon those of each part.

And this consideration leads to the controlling one that, even if each community had the necessary understanding of its own needs, and the means for satisfying those needs, it would be glaringly absurd to suppose that it has the knowledge and power and disposition to adjust the supply of those needs to the needs of its neighbors.

Under the predicted centralization, the present squabbles between neighboring towns, over sources of supply, and the spectacle of a great city supplying its own needs with practical disregard of the needs of other communities within reach of its supply line, will be looked back upon with sorrowing wonder that so imperfect a civilization could so recently have existed.

MR. NICHOLAS S. HILL, JR.: The author would like to say to Mr. Trautwine that the illustration of the increase in per capita consumption notwithstanding the introduction of meters, was not made for the purpose of showing that meters were not productive of economy; but rather to prevent the water works man, in designing his distribution system, from saying that because of the introduction of meters there would be no further increase. If Mr. Trautwine closely followed the paper he would remember that the author said, particularly in the case of Cleveland, that if meters had not been installed the per capita consumption today would have been probably 100 gallons in excess of what it is at the present time; showing that although there was a gradual and continued tendency toward an increase, notwithstanding the introduction of meters, yet the saving due to the introduction of meters was enormous.

The author also wants to say that he thinks that this matter of having insufficient mains to provide for proper expansion of the system from time to time, as the requirements may demand, is one of the wrong financial policies upon which our water works systems are carried forward. If it can be shown that by laying a 10 inch pipe in lieu of a 6 inch today, the gross cost of that plant twenty years hence would be less than by laying the 6 inch main today and laying another 6 inch main ten years hence, it is only fair to

assume that the policy of laying a 10 inch main today is going ultimately to redound to the better financial interests of the plant.

The point that the author wants to make is this, not to let the first cost override all other considerations; a tendency to which the American people are or have been strongly inclined; an inclination which is characteristic of every new nation and every new community, because of financial stress and the difficulty of raising the funds for the first outlay. But we are fast getting into such a financial position that we are enabled to sit down, sharpen our pencils, and consider not first cost alone, which is only one element of the cost. If we could only fully realize that the first cost is only one element of the cost, we could sharpen our pencils and determine what is going to be the lowest average cost, not the first cost only, but also depreciation, interest, maintenance, and replacement, in fact, all the elements that go to make up the total cost and should be included therein.

MR. PAUL HANSEN: May the speaker ask Mr. Hill what method he would employ in the designing of an ordinary cast iron distribution system; that is, how many years in the future he would think it necessary to provide for and how he would go to work to forecast the future proper demands within the period taken?

MR. NICHOLAS S. HILL, JR.: The author tried to take up that question in the paper which he presented to the Association, by showing the relative cost at the end of a period of twenty years, of laying a small main now, and duplicating it at the end of ten years, compared with the cost of laying a larger main now. This is the simplest way that he knows of getting at it. In general, his experience has led him to believe that it is economical to plan at least twenty years ahead; that a water works department or water works company will be in pocket at the end of twenty years, if today they plan for that period rather than to plan simply to take care of immediate needs as they see them today.

MR. J. N. CHESTER: Most of us have visited Washington and probably been taken by professional guides out to that side of the capitol which does not face the city and have been told by the guide how when George Washington and his architect laid out the city they intended that it should be built to the east of the capitol building,

but the real estate dealers and others decreed to the contrary, and it grew in an absolutely opposite direction from what Washington intended, when he laid out the city.

Now while Mr. Hill's paper presents a compilation of a great deal of data, especially as to monthly, daily and hourly consumption, which is valuable for reference, his conclusions in the latter part of the paper, and the theories laid down, it would seem are applicable more to new towns and cities and to new conditions than they are to the conditions that we must meet. The cases in which engineers east of the Mississippi River are now called upon to design entirely new distribution systems are very infrequent; in fact, do not occur in a lifetime with some of us; but the problems against which we are constantly bumping our heads are those of the cities now in existence, and they are being drawn hither and thither by not only the real estate agent but by the location of new factories, public institutions, railroad shops, etc.; all of which create abnormal conditions, and it is not a matter of what can you do theoretically, but what can we do to make the best use of what we have and add to the present installation sufficient to meet the demands that are being created. Butler, Pa., nestled down among the hills, thirteen years ago had an average consumption of not quite 2,000,000 gallons per day. The Standard Car Wheel Company located its plant at that place, and doubled the population of the town in three years. It was not a matter of theory, it was not a matter of taking up old pipes, but we reinforced the old system and also got mains into that part of the town where the growth had been created for this enormous new industry.

It is not a new thing, especially in the district that we have operated in, which is east of the Rocky Mountains, to find cities being drawn on in just that way; the speaker cannot see just how we can apply these formulas of cost and still best meet local conditions. We must meet the conditions that we have.

Another thing to which exception may be taken in Mr. Hill's paper, is the statement that fires seldom occur at times of maximum consumption. The speaker has been responsible for the operation of a number of water works, and can say that fires do often occur at times of maximum draft, and when they do they are very embarrassing, especially when you are not possessed of the capacity to cope with them.

MR. W. S. CRAMER: The speaker was particularly interested in Mr. Hill's reference to the effect of sewering cities and the increasing population with reference to increasing the per capita consumption. The experience in Lexington, Ky., was that in 1900, with 20 per cent of the city sewered, and with 96 per cent of our supply metered, the per capita consumption was 40 gallons; in 1912, with 40 per cent of the city sewered, with an all metered supply, the per capita consumption had risen to 60 gallons per capita.

MR. H. C. HODGKINS: The first statement made by Mr. Hill, if the speaker remembers correctly, was that the distribution system would cost about 60 per cent of the entire cost of the plant. A rule of thumb that the speaker has used in the central west where the works consisted of a standpipe, no expensive reservoir, no filter plant, and in towns ranging from 10,000 to 20,000 population, was that as soon as he knew the tonnage and cost of iron pipe he would multiply the cost by 3 and so arrive at a result that was generally within a few thousands of dollars of the cost of the plant.

An experienced man frequently finds that his plant has become inefficient and too small in capacity; occasionally he may find that it is too large in capacity, when of course he is asked, "Why were you extravagant when you designed and built this plant?" In view of such experiences this paper is particularly *apropos*, and is excellent in its statement of fundamental principles and in the general directions given as to methods of procedure. But after all, these are simply for basing judgment and not an absolute rule; for instance: when the City of Toronto employed an engineer, in about 1906, and paid him what seemed to us in those days a very large fee, $15,000, he prepared an elaborate table to the effect that in 1940 the City of Toronto would have a population of 450,000. Before one-third of that time had elapsed the population had reached that figure, and it would be a very difficult matter to find anyone in Toronto now who does not believe that in 1940 it will have 1,000,000 population. So that the figures that he made up would under present conditions appear to be poor planning; yet the speaker does not think anyone will undertake to say that he did not use good judgment or that he was not well equipped for the work he had in hand.

The question of your pipe distribution becomes occasionally a very pertinent one; for instance: you find some systems where they pump directly into the mains; and where hydro-electric power is very cheap, and it is a proposition then of pumping with electrically driven turbine pumps directly into such a system. If Mr. Hill wants a real nut to crack, let him proportion such pumps to provide a high maximum load, and also for a minimum load, and see where he would come out.

MR. W. C. HAWLEY: It would seem that with reference to the per capita consumption we must take into consideration the rate at which water is sold. If the quantity rate is high and the minimum rate small, there will be a minimum use of water, whereas much more water will be used, and leakage not watched closely when the minimum rate is such as to allow a liberal quantity of water, or when the quantity rate is low; and these conditions will have to be considered in all cases. It is difficult to do this because of the shifting of rates by our city councils without carefully studying the costs of furnishing the water.

MR. J. M. DIVEN: Mr. Hill speaks of the contours. There are so many things we want to get on our distribution map that contour lines have been found greatly in the way and the speaker has adopted the practice of indicating the elevation of fire hydrants above datum in figures on the maps.

Mr. Hill spoke of the insurance maps getting out of date. These very convenient maps are now being kept up to date by the insurance people. A man comes around once a year to correct them. Slips with all changes are pasted over parts of the maps where changes have occurred.

MR. N. S. HILL, JR.: The author wants to make more clear the point that he wished to make in regard to Mr. Chester's comments on the paper. We all realize that in every community there are changes which cannot be foreseen; some of these changes are sudden, and in many instances they are directly opposite to the preconceived notions or the estimates of the engineer. It is manifestly impossible to prepare for the unexpected; nevertheless that fact should not in any way deter the water works engineer or water works superintendent from making the best possible future estimate

he is able to make with the data in hand. Failure to do so is a mistake. In the long run, if such estimates are made, notwithstanding the sudden conditions which may arise and have to be met from time to time, the total investment in the distribution system at the end of a given period will still be less. The speaker also believes that in many cases, if the local conditions of the community, the trend in adjacent communities, and the trend of development around the particular community, are noted, some conception may be had of the probabilities in the special community under consideration; at least a much more clear conception than would be arrived at by the mere haphazard method of laying pipe here and there, or in some other place, simply to meet such demand as eventuates. In all these estimates, such as a previous speaker brought up in the case of Toronto, all engineers are liable to error, and if we conducted all our business on the plan of refraining from expressing our opinions, and saying that we could not estimate because something unforeseen might happen, we would not go very far along the road toward progressive and intelligent designing.

MR. P. GEAR: The older men in our water works plants will all admit that thirty or forty years ago the water works engineers were not such specialists in water works practice as they are today. Perhaps there is now no class of engineers who are better prepared in their line of work than the water works engineers. When our distribution system was first laid out, the pipe arrangment was suitable enough for it, but with growth and development of our city our distribution system was necessarily expanded. For a number of years our commissioners did not consult any engineer as to the distribution system, but laid such mains as seemed desirable to themselves. However, our distribution system never failed us when it was called on in an emergency, although some of the pipes which were laid were later found to be too small, and had to be taken out. Our city is built on a bank of the river, so that there is no chance for growth except in one direction, and that is toward the reservoir, which helped our distribution system.

THE RAPID FILTER PLANT AT EVANSTON, ILLINOIS

By Langdon Pearse[1]

The installation of a filter plant was urged because of the poor condition of the water in Evanston, both from the hygienic and aesthetic standpoints. The intake is only one and one-sixth miles offshore, well within the range of drift for the sewage of Evanston and Wilmette, the greater portion of which is discharged on the lake front. In the winter of 1911–1912 a severe threatened epidemic of typhoid was averted only by the emergency use of chloride of lime.[2] From time to time breaks in the intake pipe have been found, thereby receiving water nearer inshore.

When the matter was agitated in 1912, Mr. W. W. Jackson and the writer made a report, in August of that year, recommending the construction of a plant of the rapid-filter type. By a popular vote, in the same fall, a bond issue was authorized. Plans and specifications were prepared by Mr. George W. Fuller, of New York City, and the writer, on which bids were received in April. Active construction work commenced in June, 1913, under our direction, with Mr. C. G. Gillespie as the resident engineer, the work being substantially completed in August, 1914. Since that time, Mr. Gillespie has been in charge of the operation of the plant.

Doubtless the water works man will ask why the plant was made of 12,000,000 gallons capacity for an estimated population of about 30,000. The reason for this is the abnormal daily average pumpage in the summer time, the daily average frequently running 12,000,000 gallons per day for a continued period of hot weather, with peak loads for four hours as high as 17,000,000 gallons per day in the afternoon, and on one day after the plant went into service lasting twelve hours. The average daily pumpage by the year has been about 6,000,000 gallons per day for the last ten years (Fig. 1), the effect of increase in population having been taken

[1] Division Engineer, The Sanitary District of Chicago; also, Hydraulic and Sanitary Engineer.

[2] See *Proc. Ill. Water Supply Assn.*, 1912.

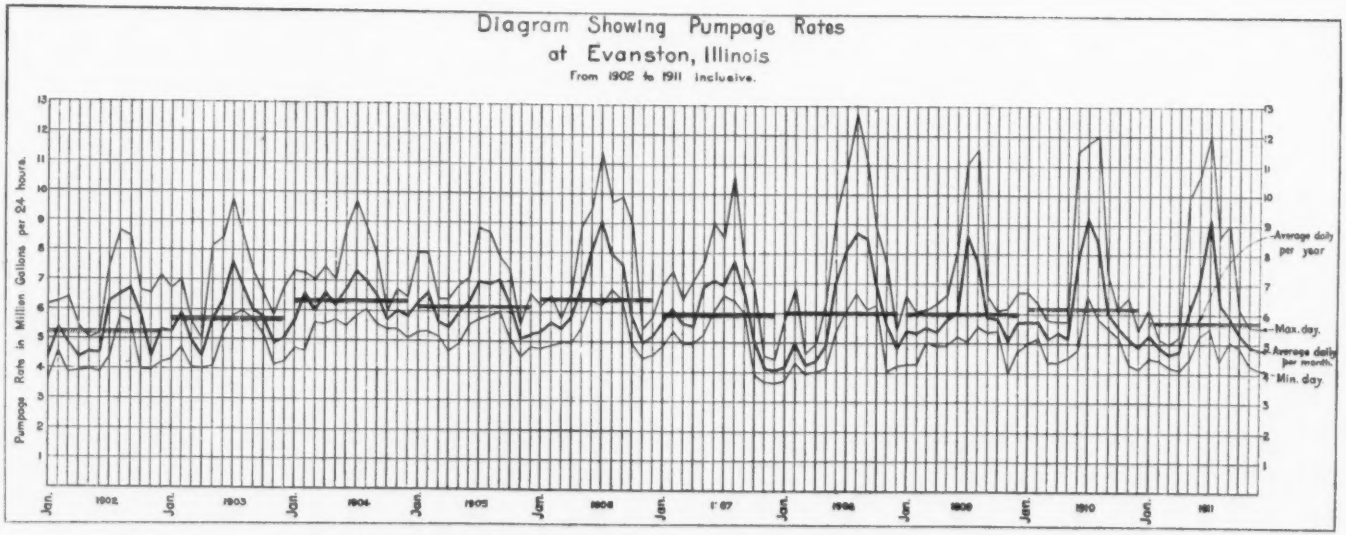


FIG. 1. DIAGRAM SHOWING PUMPAGE RATES AT EVANSTON, ILLINOIS.

care of by inspection of services and leaks. This large use of water is due principally to lawn sprinkling, since the pumpage drops suddenly in summer time on cloudy, and particularly on rainy days (Fig. 2). With the condition in mind of continued daily loads, and the possibility of a healthy growth of population, 12,000,000 gallons capacity seemed a nominal size for this community. This rating is based on the usual rating of 125,000,000 gallons per acre per day.

The filter plant is located on Sheridan Road about one mile north of the center of the city on a site adjoining the Northwestern University and 300 feet from the existing city pumping station. A low-lift pumping station built adjoining the present pumping station is equipped with three centrifugal pumps, one of 10,000,000, one of 8,000,000, and one of 6,000,000 gallons per day capacity, with a total lift varying from 25 to 40 feet. These are geared to steam turbines, with a guaranteed duty in excess of 69,000,000 foot pounds per 1,000 pounds of dry steam for the large units operating condensing with 26 inches vacuum or over. A surface condenser is used, placed directly in the force main, inside the pumping station. A 30 inch cast iron force main conducts the raw water to the entrance to the mixing chamber, a Venturi meter being placed on the line to measure the pumpage.

The mixing chamber (Fig. 3) is about 96½ feet by 14 feet in size, with a depth of 18 feet, having a total capacity of approximately 170,000 gallons, giving a nominal mixing period of twenty minutes. The basin is constructed entirely of reinforced concrete, divided into bays by wooden baffles to maintain velocities of approximately 1 foot per second. The mixing chamber lies between and is part of two coagulating basins (Fig. 4) each about 39½ by 96½ feet in size, and 15 feet deep, having a combined capacity of approximately 830,000 gallons, giving a nominal period of sedimentation of one hour and forty minutes. These are constructed entirely of reinforced concrete with a groined arch roof, each compartment being divided by two concrete baffles into three bays to insure circulation

The coagulated water flows in a concrete channel across the space left for the extension of the filters to six rapid-filter units, each 23½ by 36 feet inside dimensions, having an aggregate filter surface of 4425 square feet. The filters are grouped on both sides of a pipe gallery, over which is a platform with an operating table for each filter. All the filter tanks, floors and roof are of reinforced

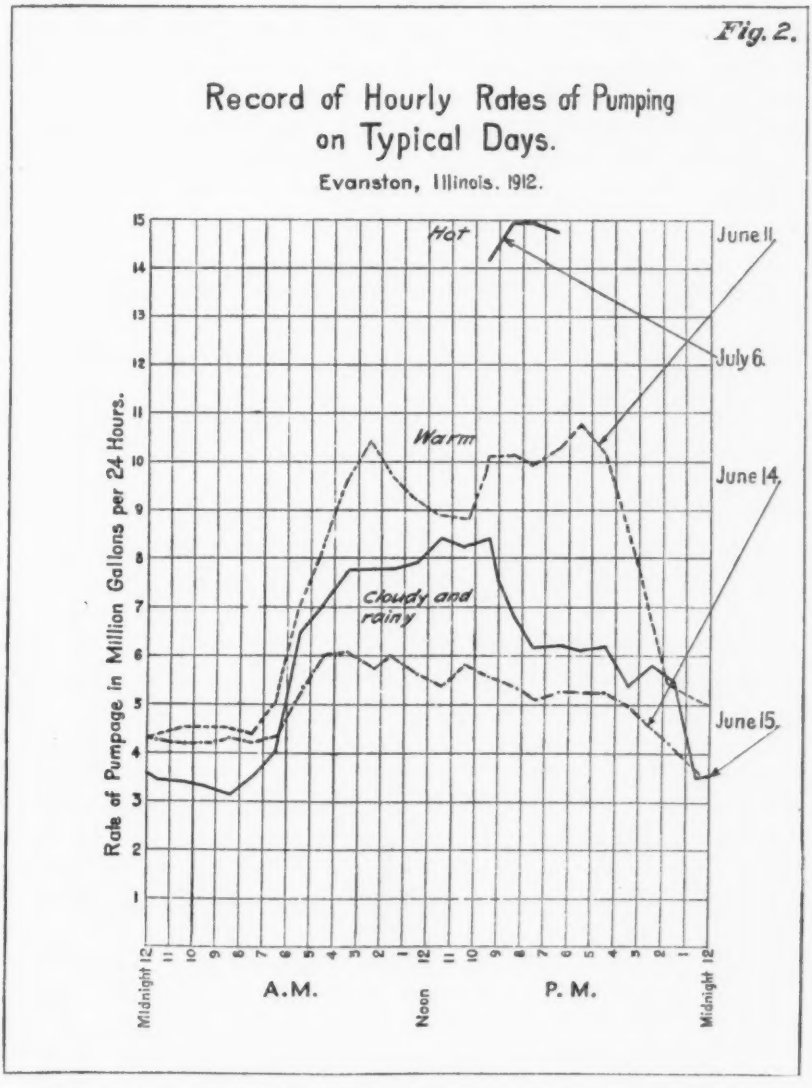


FIG. 2. RECORD OF HOURLY RATES OF PUMPAGE ON TYPICAL DAYS, EVANSTON, ILLINOIS, 1912.

concrete. Hydraulic valves are used throughout, the controllers for the filters being of a modified Vivian type. The wash water drain, filtered water conduit and raw water conduit are built one over the other, forming a reinforced concrete structure down the center of the pipe gallery. The house covering the operating floor and a part of the filters is of brick with a concrete roof, the inside being lined with a light yellow vitrified brick. The design is so made that the operator can see the entire filter bed at time of washing.

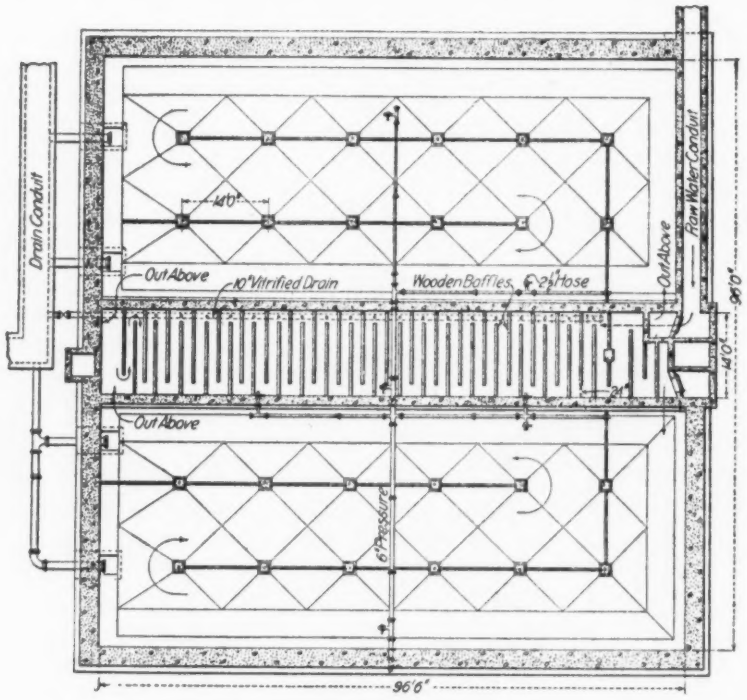


FIG. 3. PLAN OF MIXING CHAMBER AND COAGULATING BASINS, SHOWING BAFFLES.

Both filters and head house are placed above a covered filtered water reservoir, 154 by 161 feet in plan, 12 feet deep, divided into two basins having a total capacity of approximately 2,000,000 gallons. This basin has a groined arch roof, reinforced where necessary to carry the weight of the head house and filters. The standard spacing for the arches is 12 feet 6 inches on centers, with a rise of

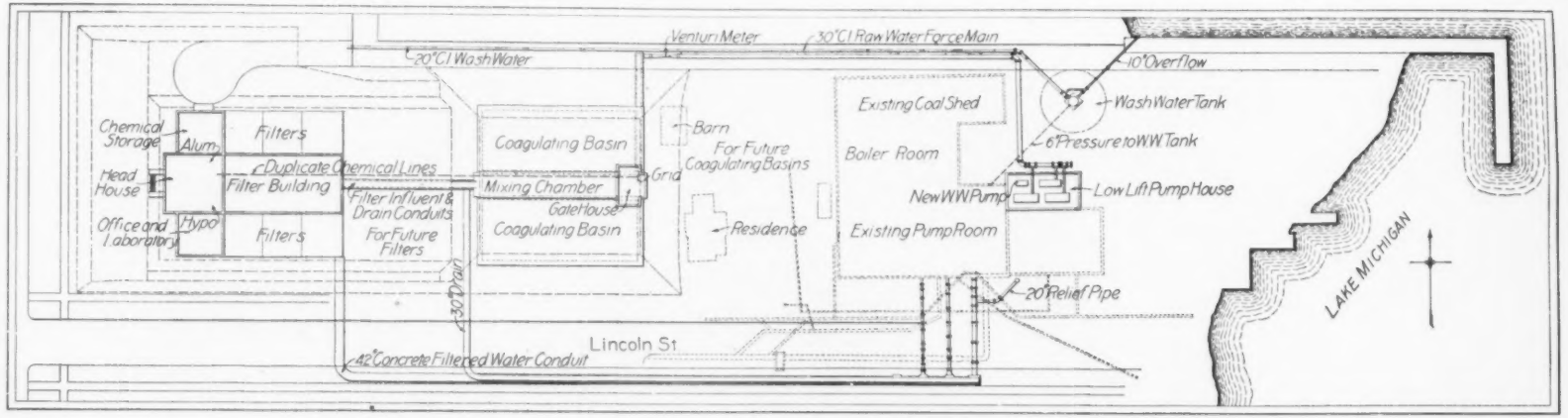


FIG. 4. RELATION OF TANKS, FILTERS AND MECHANICAL EQUIPMENT OF EVANSTON FILTER PLANT

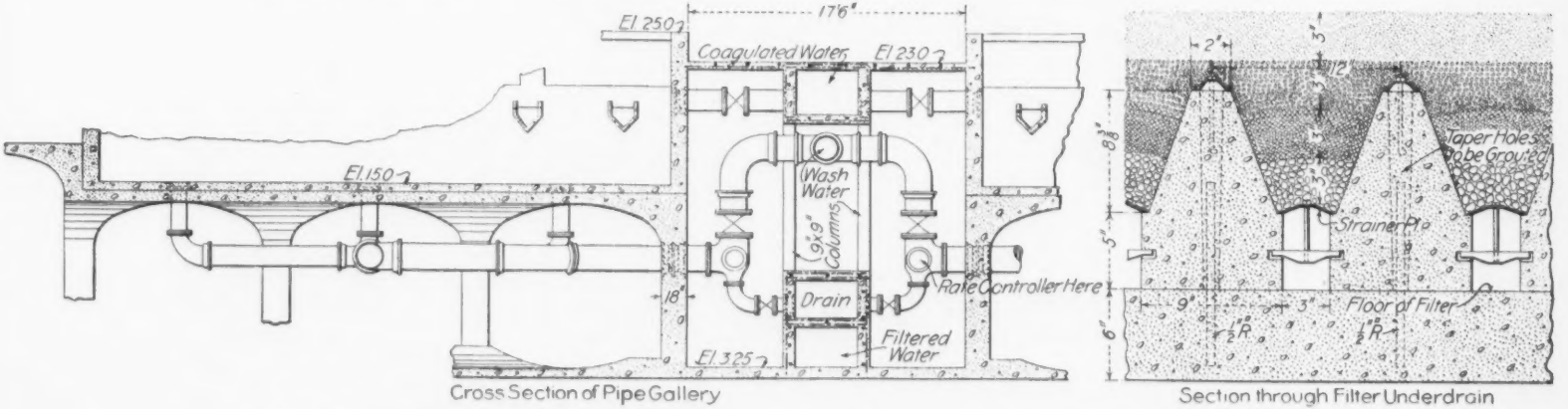


FIG. 5. CROSS SECTION OF RESERVOIR, PIPE GALLERY AND UNDERDRAINS, EVANSTON FILTER PLANT

2 feet 9 inches and a thickness of 6 inches at the crown. The foundation is of firm clay so that the thickness of the floor arches is only 6 inches at the thinnest point.

The two story head house at the head of the filter gallery has two wings, one story each, built of reinforced concrete and brick with prepared roofing. The dimensions of the head house are approximately 28 by 91 feet, and of the filter wing 75 by 36 feet. In the head house are placed the tanks and apparatus for the proportioning and application of the coagulating and sterilizing chemicals, the recording gages, laboratory office, and chemical storage. The second floor of the head house is served by a hydraulic elevator.

The design of the rapid filter units includes an under drain system with perforated brass plates, set at the bottom of valleys in the fashion of the Minneapolis, Grand Rapids, and other plants (Fig. 5). A novel feature, however, is the omission of the wire screen and the use of 12 inches of graded gravel, on top of which the sand is placed. The wash is a high-rate water wash, supplied by a gravity feed from a steel tower tank of 100,000 gallons capacity erected behind the present pumping station on the lake front. It is fed by a bleeder from the present high service mains. Fluctuations in the pressure due to the drop of level in the wash water tank are taken care of by a controller to be placed in the line at the entrance to the filter gallery (Fig. 5).

The work was carried on under a general contract. Owing to the situation, it was impossible to bring material in except by teams, a haul of approximately one mile from the nearest railroad switch being required. Owing to lack of storage room the contractor developed a plant for the elevating and storage of the gravel and sand in bins to minimize the handling by hand. The teams dumped into a hopper from which a belt conveyor delivered the material to the sand or gravel bins. Storage sheds for cement were built alongside the bins. A concrete mixer discharged into two-wheeled buggies on an elevator for raising or lowering the cars of concrete to the appropriate level for placing. One inch yellow pine flooring was used for form work wherever possible, with 2 by 4 inch studs spaced about 16 inches on centers tied with very heavy wire.

The inverted groined-arch column bases were formed up continuously in rows by the use of a "spider," a metal frame consisting of 1-inch angles making a square, from each corner of which malleable castings of the shape of the groin converged to the base

at the center, where they were held together by plates. In use, the angle frames were set on the two 6-inch floor form strips and held there by pins. After running a cut-off strip over each pair of legs and getting the base shaped, the form was removed to the adjoining base and the corners smoothed up.

The groined-arch forms (Fig. 7) for the roof were built in a manner different from that usually employed on such work. The form units were framed in the carpenter shop and transported to place on a pair of wheels. They filled the squares between the column corners, leaving a width approximately that of the column to be

FIG. 6. STEEL SCREED FOR INVERTED GROINED ARCHES

filled on the job, with short pieces of 1-inch flooring nailed in place by carpenters (Fig. 8). This method was feasible because of the short span. The groined-arch forms were carried on stringers resting on the vertical tie studs of the column forms. The forms were stripped at a minimum time of five to seven days, ten days being secured wherever possible. For the construction of the 30 inch wash water drain and 42 inch filtered water conduit, suitable circular collapsible forms were built of wood. At the bends a built up form was made of laths, plastered smooth with ivory wood fiber plaster, smoothed up with paraffine wax dissolved in kerosene. The forms were destroyed before removal.

In the construction of the chemical solution tanks in the head house and the valve chamber at the entrance to the mixing chamber, the contractors used a novel adaptation of the moving form used in grain elevator construction. The form (Fig. 9) consisted of well braced sheets making an inside and outside form 4 feet high. This was supported by hangers carried on jacks which were moved upwards on stout iron rods embedded in the concrete. The twisted

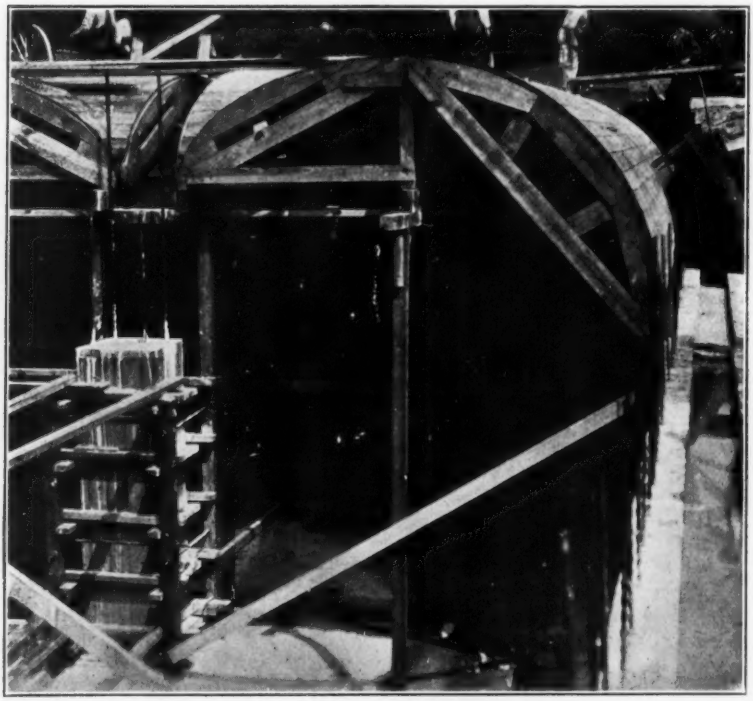


FIG. 7. FORMS FOR GROINED AND BARREL ARCHES

steel was placed as the form moved upward. The idea was to move the form upward at such a rate that the concrete exposed below the form would be set sufficiently to be self supporting. As a result, a very smooth finish was obtained at small cost. Clearly such a method is easily applicable only where a structure has the same plan throughout its height. In the case of the solution tanks the form was jacked upward day and night for five days through a height of about 13 feet. A similar device was used to build the

FIG. 8. ADJUSTMENT SPACE BETWEEN ARCH FORMS

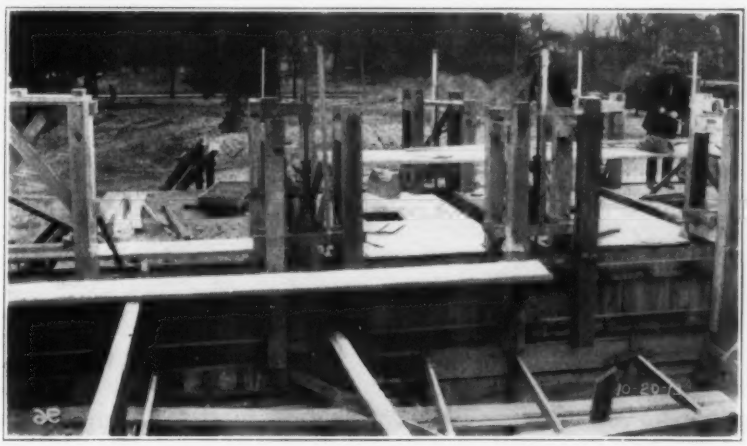


FIG. 9. MOVING FORM FOR CHEMICAL SOLUTION TANKS

reinforced concrete baffles in the coagulating basins, the reinforcing, however, being placed first and each side form being jacked up separately. The device worked well on the baffles and on three out of five solution tanks. Despite three coats of asphaltum paint, two tanks showed a few leaks which proved generally to be on horizontal lines, where the moving form had pulled. In one tank these were stopped by liberal applications of asphaltum, applied hot.

In the filter boxes the gutters were cast in place prior to the forming of the underdrains. Neat rounded edges were secured by a

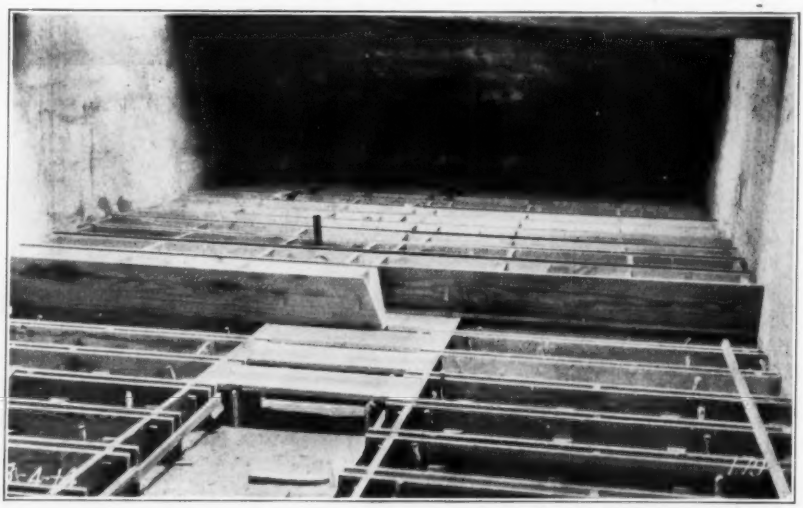


FIG. 10. RIDGE BLOCK FORM, EVANSTON FILTERS

metal screed tool. The underdrain system was cast in place, complete, instead of casting the spanning block outside and placing later. The procedure was as follows. Holes were drilled in the floor to receive the dowels. For this work a small 40-pound steam drill was found most economical. In these holes, the dowels were grouted, a test being made after ten days set. Then the brass deflector plates were set over the three rising pipes in the bottom of the filter, and the bottom thoroughly cleaned. The forms were then built up as shown in Figure 10. The bottom pieces to form the waterways were carefully adjusted and set in lime cement mortar. They were separated by removable wedges. On these sat the block forms.

The entire wood forms were made up for three one-quarter filter units, and were thoroughly treated with one part kerosene and two parts paraffine applied hot. Small blocks were left to form the indents for the yokes. The essential points were to preserve full waterways and obtain true level seats for the brass strainer plates.

The excavation was made on all the mass work with a Thew shovel, loading two-horse bottom-dump wagons with which the spoil was carried to adjoining lots or dumped on the lake front. The earth was fairly stiff, so that no sheeting was required except in trenches left open for days. The upper 5 feet of excavation was loam and

FIG. 11. HEAD HOUSE, EVANSTON FILTERS

sand containing some water, under which a clay stratum was found, free from water. Some of the sand from the excavation was suitable for use in the concrete, but the major portion of the concrete was made with torpedo sand and gravel brought from pits along the Fox River. The imported sand was found somewhat unsuitable, owing to the lack of fine material, so that a mixture was made of one part plastering sand and five parts torpedo sand for general use. This made a nicely working tight concrete.

The filter gravel was brought from the Atlantic beaches near Cape May, in New Jersey, but required hand cleaning before placing, to remove shells, dried seaweed and other foreign material. The sand was brought largely from Crystal City, Missouri. At first

this contained considerable fine material. After removing about 25 per cent by continued washing the effective size was about 0.43 mm., with a uniformity coefficient around 1.44. With a small proportion of Cape May sand added the effective size was increased to 0.47.

In the application of the solutions, through long lines at distant points, the novel feature is the use of lead solution lines, fed by an ejector. This introduces into the lines sufficient water to keep a high velocity. Such lines should be kept straight as far as possible. Incrustation occurred early with both "hypo" and "alum" lines. Rodding of the lines so far has kept them clear. A riser, 6 inches high, inside the solution tanks on the outlet pipe, helps also. The grids for application of coagulant and chloride of lime were early removed, for cleaning, and have not been replaced. In the mixing basin thorough mixing ensues.

One of the most interesting points was the strainer system. Prior to the construction, the existing underdrains of this type were studied, their history developed and provision made for the use of soft brass strainer plates of increased thickness, as well as for increasing the net area of the holes, and placing brass baffle plates over the pipes through the filter bottom. Some of the data collected is summarized in Tables 1 and 2. The original Minneapolis plate was a so called Tobin bronze and showed a very low ductility. Judging from previous strainer construction the details planned for Evanston were entirely safe and reasonable.

After the beds were put in operation, a number of the $\frac{1}{4}$-inch bolts broke, chiefly because of imperfections at the head, practically none breaking at the root of the thread. In view of the seriousness of breaks caused by flaws in the metal, the $\frac{1}{4}$-inch bolts were replaced with $\frac{3}{8}$-inch diameter Parsons bronze bolts, with heavier yokes. The tests of the bolts are given in Table 3. These show a more ductile metal in the smaller bolts. The work was rebuilt, every care being taken to insure true work to avoid secondary or eccentric stresses. The wash water valves were also adjusted to prevent water hammer by quick opening. At no time has a pressure on the plates been observed over 5 pounds per square inch. Yet a number of $\frac{3}{8}$-inch bolts have broken, some at the root of the thread, some by irregular jagged breaks, practically all showing a non-uniform crystalline fracture, a large portion being large crystals. Bolts actually broken in test showed a very uniform fine-

grained texture. Bending tests showed that some bolts could be bent double, while others snapped before 90 degrees was turned. In no case is there anything to indicate the metal has been overstrained, as the cross-section is practically unchanged. Hence the only conclusion is that the Parson bronze metal bolts are very variable in physical properties, proving frequently defective without warning. Monel metal bolts are now being used to replace breaks.

Subsequent investigation showed that considerable difficulty had been experienced on general water supply work by the Board of

TABLE 1

Physical and chemical tests of strainer plates from Louisville, Minneapolis and Cincinnati

Physical Tests

FILTER PLANT	LOUISVILLE	MINNEAPOLIS	CINCINNATI
Birmingham wire gage	14	16	15
Dimensions, in	0.084 x 0.737	0.066 x 0.75	0.079 x 0.514
Area, sq. in	0.062	0.046	0.040
Reduction of area, per cent	45.2	10.8	52.5
Elastic limit, lbs. per sq. in	54850	47800	40650
Ult. strength, lbs. per sq. in	60100	55450	56250
Elongation in 2 in., per cent.	27.5	10	35.5
Fracture	Silky	Broke at perforation	Silky

Chemical analysis in per cent

Copper	65.48	60.81	66.96
Tin		0.77	
Lead	0.21	Trace	0.14
Iron	0.08	0.05	0.26
Zinc	34.23	38.37	32.64

Water Supply of New York City, and that bolts even as large as 2 inch diameter had broken under no strain (See Brass in *Engineering Construction* by A. D. Flinn, Municipal Engineers, City of New York, Feb. 25, 1914). This points to the need of the utmost care in selecting non-corrosive alloys of high strength, even from careful manufacturers, and the present indications are that such metal should be used with great caution.

The operating results obtained at Evanston are of interest as this is the first large modern plant on Lake Michigan. One of the first

TABLE 2

Data on Strainer Plates

FILTER PLANT	RATE OF WASH. VERTICAL RISE INCHES PER MIN.	STRAINER PLATES										
		Spaced on centers inches	Holes		Gage, B.W.G.	Thickness inches	Bolts		Channel width inches	Opening holes; per cent of filter area	Loss of Head Through Plate for Wash Rate	
			Diam. in.	No. per sq. ft.			Spacing c/c	Diam. in.			Feet	Based on C= 0.74
Cincinnati	24	12	$\frac{3}{32}$	64	15	0.072	12[4]	$\frac{1}{4}$	$2\frac{3}{4}$	0.3	$\left(\frac{1.39}{c}\right)^2$	2.65
Louisville	24	$11\frac{1}{4}$	$\frac{3}{32}$	54	14	0.083		$\frac{1}{4}$	$2\frac{1}{2}$	0.277	$\left(\frac{1.5}{c}\right)^2$	4.11
Niles	24		$\frac{3}{32}$	48	12	0.109				0.23	$\left(\frac{1.81}{c}\right)^2$	6.00
Grand Rapids	24	12	$\frac{1}{16}$	72	16	0.065	12	$\frac{1}{4}$	3 to $3\frac{3}{4}$	0.15	$\left(\frac{2.77}{c}\right)^2$	14.0
Minneapolis												
Old	24	12	$\frac{1}{16}$	72	16	0.065	12	$\frac{5}{16}$	3 to $3\frac{3}{4}$	0.15	$\left(\frac{2.77}{c}\right)^2$	14.0
New			$\frac{3}{32}$	48	14	0.083	4[2]			0.23		
Evanston	20	12	$\frac{3}{32}$	72	14	0.084	13[3]	$\frac{1}{4}$	3	0.34	$\left(\frac{1.02}{c}\right)^2$	1.9
Columbus	15	$8\frac{3}{4}$	$\frac{1}{16}$	45[1]		$\frac{1}{16}$		$\frac{3}{16}$		0.18	$\left(\frac{1.44}{c}\right)^2$	3.8

[1] Per plate, $8\frac{3}{4}$ in. centers both ways.

[2] Uses 12 in. spacing of $\frac{5}{16}$ in. U bolts and $8\frac{1}{2}$ in. spacing of $\frac{3}{8}$ in. hook bolts.

[3] Changed to $\frac{3}{8}$ in. bolts, 13 in., center to center.

[4] U bolts and yokes.

NOTE. Coefficient of discharge for orifice, "c," was selected at 0.74 from actual tests on similar orifices.

developments was exceedingly short filter runs, the loss of head building up to 10 feet in three hours, frequently in thirty minutes. Investigation showed that this was apparently caused by large amounts of diatoms present, chiefly Asterionella (400 to 2000 standard units per cc.). The interlacing arms of this organism made almost a water-tight mat on the surface of the filter. In order to keep the wash water within reasonable bounds, whenever the loss of head ran up to 8 feet or over, the bed was shaken up, by turning on the wash water and as quickly turning off. After two or three shakes, the bed had to be washed, but at periods usually three hours or more. With the diminution of the diatoms to less than 400 standard units per cc. in November, the runs lengthened to eight to sixteen hours.

With the low turbidity and low bacterial counts in the raw water, the removal of bacteria by the filters alone is not complete, 2 to 4

TABLE 3

Tests of strainer bolts

DIAMETER OF BOLT IN.	MAXIMUM STRENGTH		REMARKS
	Actual lb.	Lb. per sq. in.	
0.25	1075	40180	
0.375	5840	86190	
0.375	5140	75720	
0.373	5960	87650	Snapped. Brittle.
0.373	6190	91030	

NOTE. All broke at root of thread. All ⅜ inch bolts Parsons bronze.

pounds of chloride of lime being used per million gallons as a finishing agent. The turbidity is entirely removed. With varying turbidities, and wide range of flow, the conditions to be met frequently tax the flexibility of the coagulating basins. A secondary application of coagulant just before the water is applied to the filter is of great service, giving a large heavy floc.

Contrary to expectations, the coagulant flocculates very readily, giving large heavy flocs with amounts of 0.6 gram per gallon and upward. In the preliminary laboratory tests of the original report, considerable difficulty was experienced in getting a good floc with low turbidities.

Running at a slight overload, the bacterial removal was over 90 per cent at times with less than 1000 bacteria per cc. on agar at 20 degrees C. in the raw water. With the lowering of the diatoms and the decrease in filter rate to a usual rating, the bacterial removal has increased. Generally 3 pounds of chloride of lime per million gallons, applied to the filtered water, proves effective as a finishing agent, removing all gas formers. One pound is too little.

Under winter conditions the wash water is averaging 3.2 to 4.3 per cent, with filter runs from four to sixteen hours long, the turbidity ranging from 7 to 50 p.p.m. In December, 1914, the results were as follows:

	AVERAGE	MAX.	MIN.
Turbidity raw water	20	40	7
Applied	15	40	4
Coagulant, gr. per gal	0.76	0.85	0.61
Chloride of lime, lb. per mil. gal	3.5	5.5	0.9
Per cent wash water	4.3	5.9	2.8
Length of run, hours	7.3	12.2	4.5
Bacteria per cc. (on agar 20 deg., 4 days)			
Raw water	664	2000	120
Settled water	464	1400	90
Filters	87	600	0
Plant	23	60	0

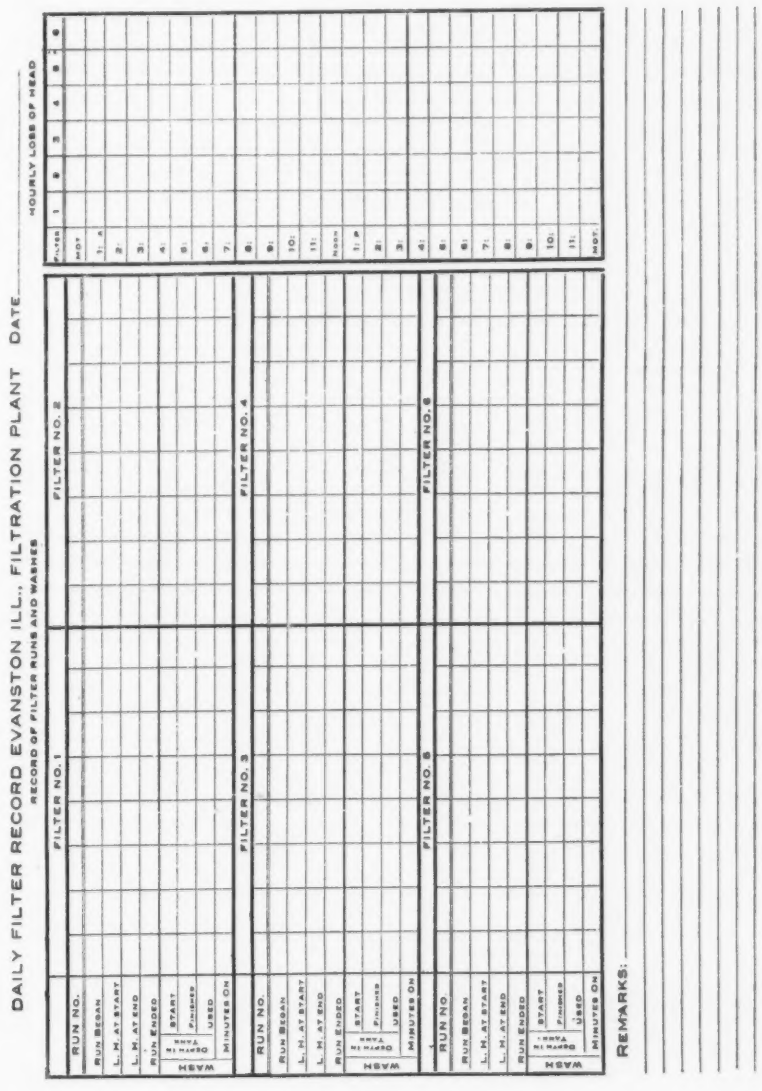
The treatment of the water at Evanston has largely eliminated typhoid. However, not enough time has elapsed to show the effect of filtration, but the results produced by the use of the "hypo" applied since January 1, 1912, are of interest. For this table the author is indebted to Prof. W. Lee Lewis, city chemist.

TABLE 4

Typhoid fever death rates per 10,000

YEAR	CHICAGO	EVANSTON
1907	17.5	21
1908	15	32
1909	12.5	28
1910	13	24
1911	10.8	28
1912	7.6	14.3
1913	10.6	13.3
1914	7.6	6.6

For convenience in keeping the operating records, several forms were devised, combining the good points of typical forms from many plants. These forms are given herewith. Forms 1 and 2 are for the filter attendant to fill in. Form 3 is filled in each day by the chemist or engineer in charge of the plant, giving a handy and complete summary at the end of each month.



FORM 1. DAILY FILTER RECORD.

CHEMICAL AND GENERAL RECORD—EVANSTON, ILL., FILTRATION PLANT. Date_____

HOUR	RATE - M. G. D.				ALUM DOSE					HYPO DOSE					REMARKS
	MASTER CONTROL		TOTAL WATER GATE	VENTURI METER	MINUTE	ORIFICE NO	HEAD FT.	THOUSAND GALS 24 HRS.	GRS. GAL.	MINUTE	ORIFICE NO	HEAD FT	THOUSAND GALS 24 HRS	LBS. M. G.	M. G TREATED _____
	MIN	READ													
MDT															V. M.
1A															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
M															
1P															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
MDT															V. M.

SOLUTION TANK RECORD

TANK NO.	1	2	3	A	B	C	
DEPTH AT MDT.							
CHARGING-START							
" FINISH							
DEPTH-START							
" FINISH							
" FILLED							
LBS. OF CHEMICAL							
LBS. PER FT. IN TANK							
DEPTH AT MDT							
PUT IN SERVICE							
DEPTH AFTER PARTLY FILLING FROM DISSOLVING TANK A							

FORM 2. DAILY CHEMICAL AND GENERAL RECORD

EVANSTON ILL. FILTRATION PLANT — MONTHLY SUMMARY OF OPERATIONS AND RESULTS — MONTH OF _____ 191_

Date	No. Filters On	HOURS: Filters Started	HOURS: Filters Run Length	MILL GALS. TREATED	Av. Filter Rate M.G.D. per sq. ft.	Yield M.G. Run per Cub. ft.	Loss of Head: Initial	Loss of Head: Final	WASHES: Hours Out of Water	WASHES: Number	WASHES: Thousand Gals. Total	WASHES: Thousand Gals. Per Wash	WASHES: Per Cent	ALUM: Pounds Used	ALUM: Grs. per Gal. Mean	ALUM: Grs. per Gal. Range	ALUM: Grs. per Gal. 2nd Filter	ALUM: Grs. per Gal. All Filters	ALUM: Grs. per Gal. Total	HYPO: Pounds Used	HYPO: Lbs. as Cl. per 10^6 Total Nitrogen	HYPO: Lbs. as Cl. per 10^6 10^-1	BASIN OPERATION: M.S.	BASIN OPERATION: North	BASIN OPERATION: South	BASIN OPERATION: C.S.	Temp. F. Room	ODOR: Raw	ODOR: Clear Wells	TURBIDITY p.p.m.: Raw	TURBIDITY p.p.m.: Influent	TURBIDITY p.p.m.: Effluent	BACTERIA-20°C Gelatin-48 Hrs.: Raw	BACTERIA-20°C Gelatin-48 Hrs.: Influent	BACTERIA-20°C Gelatin-48 Hrs.: Effluent	BACTERIA-20°C Gelatin-48 Hrs.: C.W.	BACTERIA-37°C Lit. Lac. Agar-24 Hrs. TOTAL: Raw	BACTERIA-37°C Lit. Lac. Agar-24 Hrs. TOTAL: Eff.	BACTERIA-37°C Lit. Lac. Agar-24 Hrs. TOTAL: Cal.	BACTERIA-37°C Lit. Lac. Agar-24 Hrs. ACID: Raw	BACTERIA-37°C Lit. Lac. Agar-24 Hrs. ACID: Eff.	BACTERIA-37°C Lit. Lac. Agar-24 Hrs. ACID: Cal.	B. Coli Index No. per c.c. Lac. Broth 24 Hours: Raw	B. Coli Index No. per c.c. Lac. Broth 24 Hours: Eff.	B. Coli Index No. per c.c. Lac. Broth 24 Hours: C.W.	Micro-organisms 24 Hr. Units per c.c.: RAW Hours Old	Micro-organisms 24 Hr. Units per c.c.: INFLUENT Hours Old	Micro-organisms 24 Hr. Units per c.c.: INFLUENT M. Av.	Micro-organisms 24 Hr. Units per c.c.: Diam. Pores	
1																																																		
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FORM 3. MONTHLY SUMMARY

REPORT OF COMMITTEE ON WATER CONSUMPTION AMERICAN WATER WORKS ASSOCIATION, 1913–1915

In presenting its report of results obtained to date, your Water Consumption Committee believes that it has made a beginning toward the segregation of water uses in American cities.

Our object has been to improve on the old misleading standard "Total Per Capita use"—total consumption divided by population. Conditions in different municipalities vary so greatly as to render "Total Per Capita" useless for purposes of comparison and in beginning our labors two years ago we sought to divide water consumption into two main classes—*Domestic* and *Non-Domestic*. The latter divided into three sub-classes where possible. Thus we have:

Domestic use: Or that wholly for residential or domestic purposes.

Non-Domestic use: Industrial, or railroads, factories, etc.

Commercial: Or stores, saloons, stables, boarding houses, etc., including double houses.

Public: Or fire protection, street sprinkling, sewer flushing, public buildings, schools, fountains, etc.

The responses received to our circular inquiry were both gratifying and disappointing, gratifying in the large number of returns and disappointing because many cities were unable to classify their meter readings even into the two simple divisions of Domestic and Non-Domestic use. However, we believe we are able to present to the Association a body of fairly accurate data from which valuable conclusions may be drawn, and it is our hope that this beginning will encourage all water works officials to keep their records so that segregated statistics of water consumption may be obtained.

We would recommend that the work begun by this committee be repeated from time to time until more complete records are available to our members on which to base reliable conclusions regarding the legitimate requirements of each class of water users. Concerning these various classes the following observations may be in order.

Industrial use: No community is a criterion for another in this class of use and therefore it is indispensable that data relating to industrial use should be separated from the total.

Commercial use: It will be found that this class of consumption does not vary per capita as greatly as industrial use.

Public use: Here the consumption will vary according as the water is paid for or is free in consideration of franchise rights, etc. We should coöperate with public service commissions in urging water companies and departments to adopt meter measurement and fair charges for all water used for public purposes.

Domestic use: This we have attempted to separate as fully as possible. Our results seem to indicate that the old standard of 100 gallons per capita or even the 50 gallons which has been much used by engineers of late, can now be replaced in most communities by an allowance of 25 gallons per capita daily for domestic use, and that half of this amount is a possibility where meters are in general use. But here tabulated statistics must not be applied without judgment for obviously it is unjust to compare a mill town in Western Pennsylvania having no lawns, few sewers and where poverty or economy reigns; with a suburb of New York or Chicago, having wide lawns, thorough sewerage, and the elaborate plumbing of prosperous homes.

We have attempted to classify double houses, flats, etc., as commercial use in order that our reported domestic per capita—based upon five persons per tap, see column 33 of our table—might be more accurate. Column 32 is however the more reliable index of domestic use.

The gist of our investigation is presented in the form of a diagram in which the cities are arranged in order of their total per capita use, the largest being at the top. Shaded areas show the domestic and non-domestic use, while the space between these areas represents the supply "unaccounted for." When we confine ourselves to those cities having 95 per cent or more of their taps metered, this diagram brings out the "unaccounted for" loss which we know exists in every water works system. It is apparent that this loss varies from 10 per cent to more than 60 per cent of the water delivered to the mains, and here lies an important field for economy and the elimination of underground waste.

This graphical presentation should be of use in various ways; as for example, in rate making cases under public service control, for it is too frequently presumed that all the water pumped is delivered to the consumers, and naturally, rates based on this assumption, sooner or later are found to be confiscatory.

GRAPHICAL REPRESENTATION

OF

TOTAL, NON-DOMESTIC AND DOMESTIC PER CAPITA CONSUMPTION

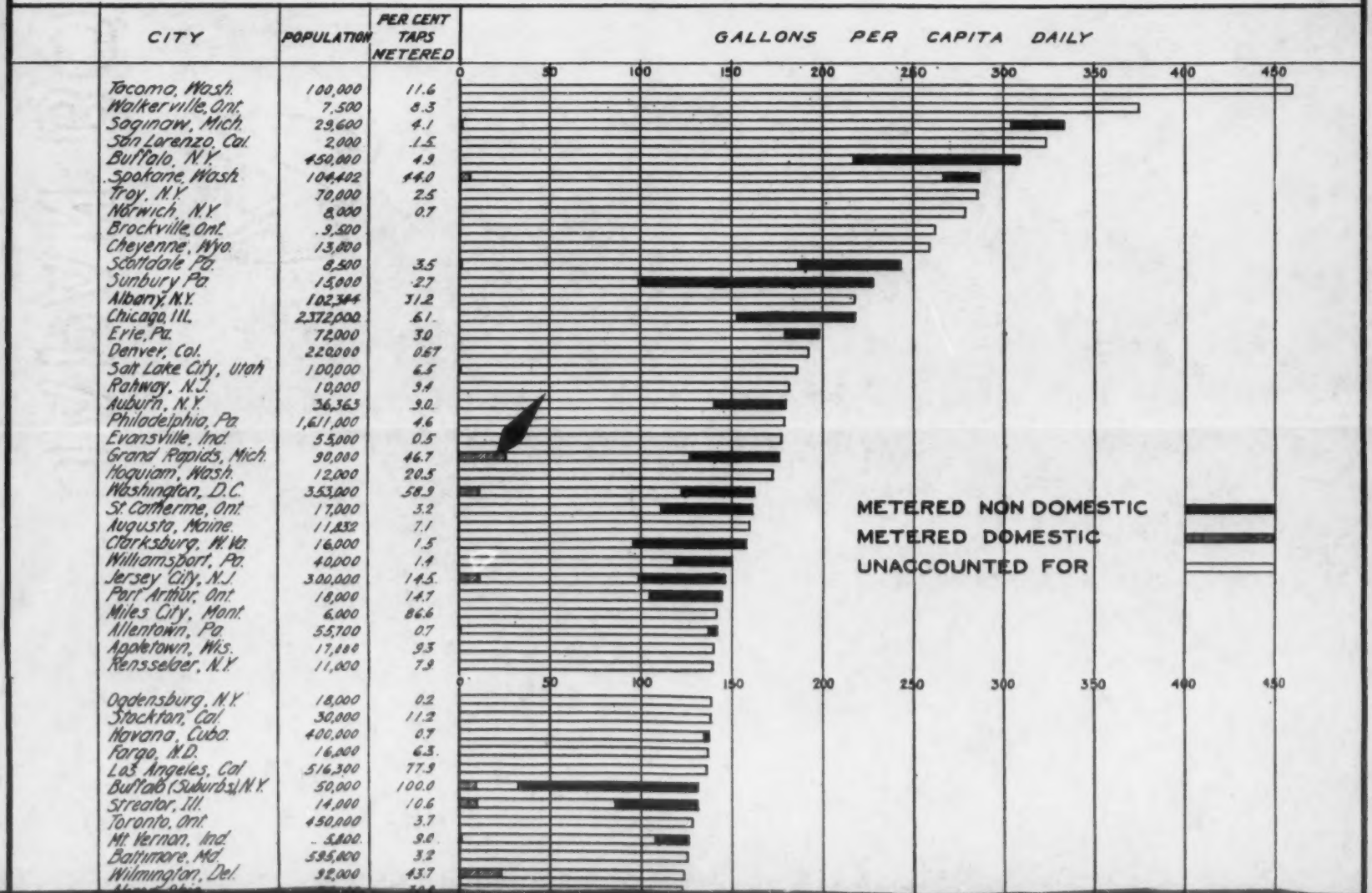
OF

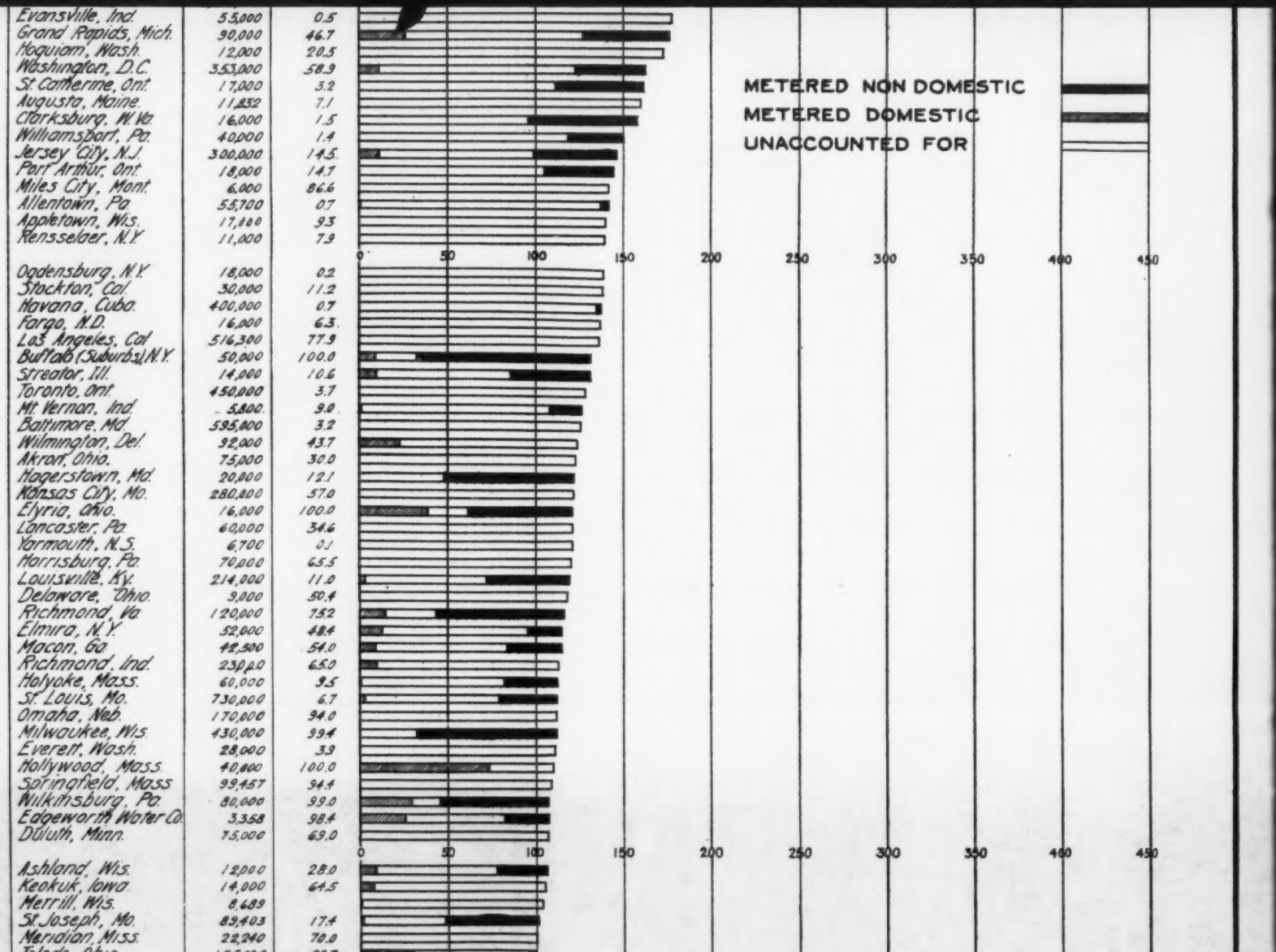
CERTAIN CITIES

TO ACCOMPANY REPORT OF

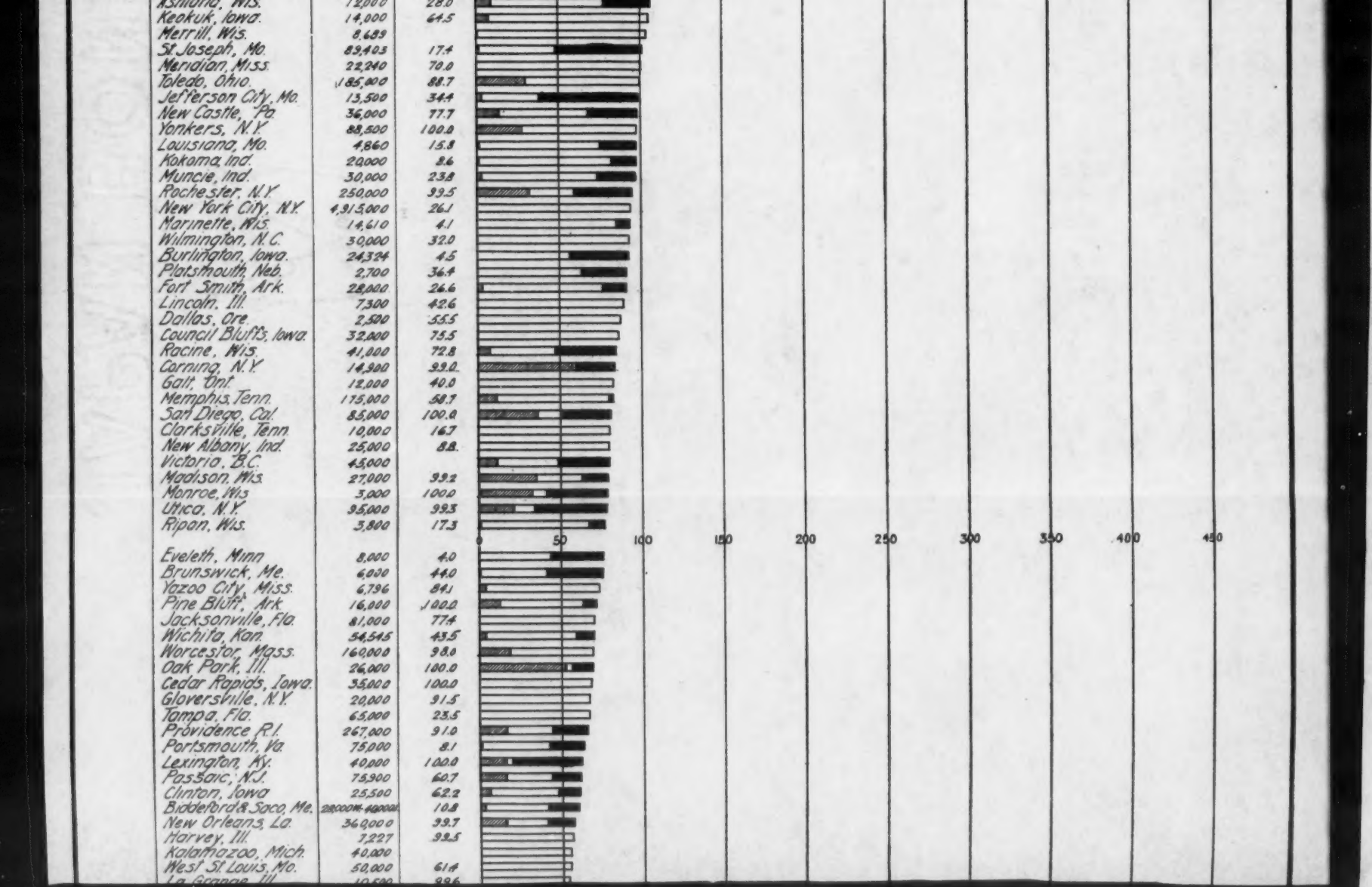
WATER CONSUMPTION COMMITTEE AMERICAN WATER WORKS ASSOCIATION

1914

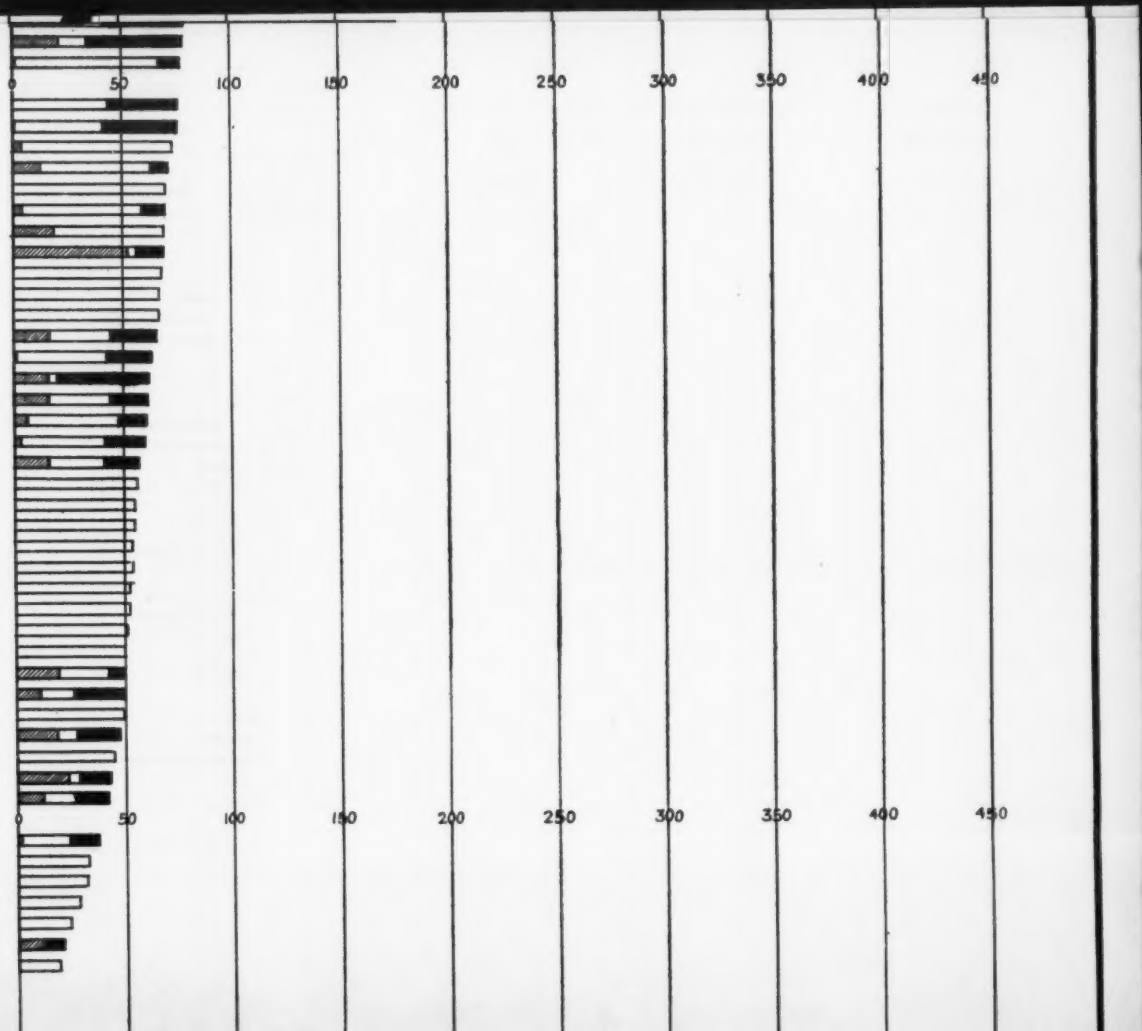




Evansville, Ind.	55,000	0.5
Grand Rapids, Mich.	90,000	46.7
Hoquiam, Wash.	12,000	20.5
Washington, D.C.	353,000	58.9
St Catherine, Ont.	17,000	3.2
Augusta, Maine.	11,232	7.1
Clarksburg, W Va	16,000	1.5
Williamsport, Pa.	40,000	1.4
Jersey City, N.J.	300,000	14.5
Port Arthur, Ont.	18,000	14.7
Miles City, Mont.	6,000	86.6
Allentown, Pa.	53,700	0.7
Appletown, Wis.	17,100	9.3
Rensseleer, N.Y.	11,000	7.9
Ogdensburg, N.Y.	18,000	0.2
Stockton, Cal.	30,000	11.2
Havana, Cuba.	400,000	0.7
Fargo, N.D.	16,000	6.3
Los Angeles, Cal	516,300	77.9
Buffalo (Suburbs) N.Y.	50,000	100.0
Streator, Ill.	14,000	10.6
Toronto, Ont	450,000	3.7
Mt. Vernon, Ind.	5,800	9.8
Baltimore, Md.	595,800	3.2
Wilmington, Del.	92,000	43.7
Akron, Ohio.	75,000	30.0
Hagerstown, Md.	20,000	12.1
Kansas City, Mo.	280,000	57.0
Elyria, Ohio.	16,000	100.0
Lancaster, Pa.	60,000	34.6
Yarmouth, N.S.	6,700	0.1
Harrisburg, Pa.	70,000	65.5
Louisville, Ky.	214,000	11.0
Delaware, Ohio.	9,000	50.4
Richmond, Va.	120,000	75.2
Elmira, N.Y.	52,000	48.4
Macon, Ga.	42,500	54.0
Richmond, Ind.	23,000	65.0
Holyoke, Mass.	60,000	9.5
St. Louis, Mo.	730,000	6.7
Omaha, Neb.	170,000	94.0
Milwaukee, Wis.	430,000	99.4
Everett, Wash.	28,000	3.9
Hollywood, Mass.	40,000	100.0
Springfield, Mass	99,457	94.4
Wilkinsburg, Pa.	80,000	99.0
Edgeworth Water Co.	3,358	98.4
Duluth, Minn.	75,000	69.0
Ashland, Wis.	12,000	28.0
Keokuk, Iowa.	14,000	64.5
Merrill, Wis.	8,689	
St. Joseph, Mo.	83,403	17.4
Meridian, Miss.	22,240	70.0
Toledo, Ohio.	168,000	23.7


Ashland, Wis. 12,000 28.0
Keokuk, Iowa. 14,000 64.5
Merrill, Wis. 8,689
St. Joseph, Mo. 83,403 17.4
Meridian, Miss. 22,240 70.0
Toledo, Ohio. 185,000 88.7
Jefferson City, Mo. 13,500 34.4
New Castle, Pa. 36,000 77.7
Yonkers, N.Y. 88,500 100.0
Louisiana, Mo. 4,860 15.8
Kokomo, Ind. 20,000 8.6
Muncie, Ind. 30,000 23.8
Rochester, N.Y. 250,000 39.5
New York City, N.Y. 4,915,000 26.1
Marinette, Wis. 14,610 4.1
Wilmington, N.C. 30,000 32.0
Burlington, Iowa. 24,324 4.5
Plattsmouth, Neb. 2,700 36.4
Fort Smith, Ark. 28,000 26.6
Lincoln, Ill. 7,300 42.6
Dallas, Ore. 2,500 55.5
Council Bluffs, Iowa. 32,000 75.5
Racine, Wis. 41,000 72.8
Corning, N.Y. 14,900 99.0
Galt, Ont. 12,000 40.0
Memphis, Tenn. 175,000 58.7
San Diego, Cal. 35,000 100.0
Clarksville, Tenn. 10,000 16.7
New Albany, Ind. 25,000 8.8
Victoria, B.C. 45,000
Madison, Wis. 27,000 99.2
Monroe, Wis 3,000 100.0
Utica, N.Y. 95,000 99.3
Ripon, Wis. 3,800 17.3
0
50
100
150
200
250
300
350
400
450
Eveleth, Minn 8,000 4.0
Brunswick, Me. 6,000 44.0
Yazoo City, Miss. 6,796 84.1
Pine Bluff, Ark. 16,000 100.0
Jacksonville, Fla. 81,000 77.4
Wichita, Kan. 54,545 43.5
Worcester, Mass. 160,000 98.0
Oak Park, Ill. 26,000 100.0
Cedar Rapids, Iowa. 35,000 100.0
Gloversville, N.Y. 20,000 91.5
Tampa, Fla. 65,000 23.5
Providence R.I. 267,000 91.0
Portsmouth, Va. 75,000 8.1
Lexington, Ky. 40,000 100.0
Passaic, N.J. 75,900 60.7
Clinton, Iowa 25,500 62.2
Biddeford & Saco, Me. 28000M-4000F 10.8
New Orleans, La. 360,000 39.7
Harvey, Ill. 7,227 92.5
Kalamazoo, Mich. 40,000
West St. Louis, Mo. 50,000 61.4
La Grange, Ill. 10,500 88.6

Utica, N.Y.	95,000	99.3
Ripon, Wis.	3,800	17.3
Eveleth, Minn	8,000	4.0
Brunswick, Me.	6,000	44.0
Yazoo City, Miss.	6,796	84.1
Pine Bluff, Ark.	16,800	100.0
Jacksonville, Fla.	81,000	77.4
Wichita, Kan.	54,545	43.5
Worcester, Mass.	160,000	98.0
Oak Park, Ill.	26,000	100.0
Cedar Rapids, Iowa.	35,000	100.0
Gloversville, N.Y.	20,000	91.5
Tampa, Fla.	65,000	23.5
Providence R.I.	267,000	91.0
Portsmouth, Va.	75,000	8.1
Lexington, Ky.	40,000	100.0
Passaic, N.J.	75,900	60.7
Clinton, Iowa	25,500	62.2
Biddeford & Saco, Me.	28000 & 10000	10.8
New Orleans, La.	340,000	99.7
Harvey, Ill.	7,227	99.5
Kalamazoo, Mich.	40,000	
West St. Louis, Mo.	50,000	61.4
La Grange, Ill.	10,500	99.6
Rockford, Ill.	53,000	93.0
Charlotte, N.C.	30,000	
Iron Mountain, Mich.	10,000	45.0
Manilla, P.I.	255,000	96.0
Chisholm, Minn	8,000	
Fort Dodge, Iowa	20,000	96.0
Quincy Ill.	38,587	63.8
Sydney, New S. Wales	776,075	3.5
Fall River, Mass.	115,400	97.8
Green Bay, Wis.	27,000	73.8
Manchester Vt.	1,500	69.0
Waterloo, Iowa.	32,000	95.4
Altoona, Pa	55,500	5.2
Calcutta, India	1,100,000	1.6
Woonsocket, R.I.	47,500	95.6
New Castle, N.S. Wales	101,000	16.8
St. Boniface, Man.	14,500	100.0
Daytona, Fla.	3000 - 10000	100.0
Yokohama, Japan.	323,990	9.1



	St. Bonnet, Mon.	14,500	1000										
	Daytona, Fla	30005-10000M	1000										
	Yokohama, Japan.	323,990	9.1										

In conclusion, we would call attention to the fact which seems to be brought out by our diagram, that the per capita water consumption of a city does not depend upon its size, nor does it seem to depend entirely upon the percentage of taps metered. The largely metered cities, as a rule, are found well down in our diagram; but there are notable exceptions of cities maintaining low per capita rates, although only partially metered.

Respectfully submitted,

JOHN N. CHESTER,
ALEXANDER POTTER,
H. J. MONTOULIEU,
W. S. CRAMER,
E. E. DAVIS,
EDWARD S. COLE,
Chairman.

Col. 32 = $\frac{\text{Col. 9} - \text{Col. 21}}{\text{Col. 8}}$ Col. 33 = $\frac{\text{Col. 19}}{5}$

Note:
Col. 32 is correct only when Non Domestic Consumption is fully metered.
Col. 33 is correct assuming 5 persons per meter.
Note:
(a)—Metered houses, with two families or more, are classed as commercial.
* Includes commercial.

CITY	MUNICIPAL OR PRIVATE	PUMPED OR GRAVITY	AREA SQ. MI.	MILES OF MAINS	RANGE OF PRESSURES	RANGE OF ELEVATIONS	POPULATION	GALLONS DAILY CONSUMPTION
1	2	3	4	5	6	7	8	9
Akron, Ohio	M	P	12.0	139.0	25–135	.....	75,000	9,180,000
Albany, N. Y.	M	P	15.7	151.2	15–90	20–280	102,344	22,486,000
Altoona, Pa	M	G	4.0	89.3	25–98	1181–1375	55,500	2,060,000
Appleton, Wis	M	P	6.5	45.0	30–65	0–70	17,000	2,380,000
Ashland, Wis	P	P	3.0	30.7	20–125	0–100	12,000	1,275,000
Auburn, N. Y.*	M	P	4.095	67.8	25–115	.....	36,363	6,550,000
Augusta, Me	M	P & G	3.2	45.18	15–130	0–350	11,832	1,895,315
Allentown, Pa	M	P	4.9	80.0	30–100	230–420	55,700	7,900,000
Baltimore, Md	M	P & G	30.7	789.0	40–110	0–460	595,000	75,200,000
Beloit, Wis	P	.....	4.0	28.3	50–90	10–30	18,000	.....
Biddeford and Saco, Me	P	P	32.0	67.05	22–83	0–149	28,000 W.–40,000 S.	1,736,000
Brockville, Ont	M	P	2.0	20.37	35–75	10–140	9,500	2,480,000
Brunswick, Me	M	P	2.0	16.0	50–100	25–100	6,000	458,000
Buffalo, N. Y.	M	P	30.0	572.0	20–60	5–120	450,000	139,000,000
Buffalo (Suburbs), N. Y.	P	P	75.0	115.0	50–100	600–800	50,000	6,576,247
Burlington, Ia.*	P	P	4.0	48.48	25–100	0–171.5	24,324	2,250,000
Calcutta, India	M	P	21.0	360.0	20–120	.....	1,100,000	36,000,000
Cedar Rapids, Ia	M	P	8.0	66.0	60–120	.....	35,000	2,400,000
Charlotte, N. C.	M	P	6.0	75.0	45–95 & 85–135	640–765	30,000	1,594,000
Cheyenne, Wyo	M	G	4.0	30.0	115–130	6030–6100	13,000	3,360,000
Chicago, Ill	M	P	.....	2400.0	25–60	.....	2,372,000	518,000,000
Chisholm, Minn.*	M	P	1.5	10.0	85–98	0–117	8,000	400,000
Clarksburg, W. Va	M	P	2.0	24.0	55–145	935–1160	16,000	2,535,000
Clarksville, Tenn	M	P	3.0	15.0	40–110	0–200	10,000	800,000
Corning, N. Y.	M	P	3.1	27.14	4–100	918–1165	14,900	1,240,000
Council Bluffs, Ia.	M	P	5.0	59.±	0–120	20–322	32,000	2,750,000
Clinton, Ia.	P	P	5.87	50.43	50–100	.....	25,500	1,570,000
Dallas, Ore	P	G	4.0	13.5	85	Level	2,500	221,920
Daytona, Fla	M	P	8.0	11.58	43–90	6–25	3,000 S.–10,000 W.	130,000
Delaware, Ohio	P	P	.....	23.0	50–65	.....	9,000	1,058,000
Denver, Colo	P	P & G	59.5	533.0	45–100	0–310	220,000	43,400,000
Duluth, Minn	M	P	.....	146.0	10–135	5–800	75,000	8,000,000±
Edgeworth Water Co	P	P	2.014	12.3	8–117	720–915	3,358	358,000
Elmira, N. Y.	P	P	8.23	97.7	65–140	.....	52,000	6,000,000
Elyria, Ohio	M	P	5.0	60.0	35–45	150–202	16,000	1,938,000
Erie, Pa	M	P	.....	143.0	15–120	0–307	72,000	15,700,000
Evansville, Ind	M	P	6.5	116.45	35–50	40–65	55,000	9,797,800
Eveleth, Minn	M	P	3.0	10.0	70–140	0–530	8,000	609,207
Everett, Wash	P	P & G	9.0	84.29	50–125	.....	28,000	3,103,940

John N. Chester
Alexander Potter
H. J. Montoulieu

W. S. Cramer
E. E. Davis
E. S. Cole,
Chairman.

PER CENT ALLOWED PUMP SLIP	PER CAPITA DAILY	TOTAL TAPS	TOTAL METERS	PER CENT METERS	GALLONS PER DAY METERED REGISTRATION	PER CENT	MINIMUM NIGHT RATE	PER CENT OF DAY RATE	OFFICIAL REPORTING
10	11	12	13	14	15	15A	16	16A	
4.0	123.0	14,000	4,200	30.0	.....	.....	2,500,000	27.0	H. H. Frost, Supt.
.....	220.0	18,428	5,756	31.2	.....	.....	.....	....	J. B. Kilbourn, Supt.
.....	37.3	13,215	680	5.15	777,200	37.5	.....	....	C. B. Campbell, Secy.
20.0	140.0	7,027	655	9.33	.....	.....	.....	....	C. H. Vinal, Supt.
.....	106.0	1,981	555	28.0	446,000	35.0	520,000 (6 pm / 6 am)	41.0	Sam Wheeler, Supt.
7.8	180.0	8,300	750	9.0	1,450,000	22.2	4,500,000	68.7	J. Walter Ackerman, Engr.
.....	160.0	2,090	149	7.14	105,000	5.5	.....	....	W. B. Getchell.
0	141.9	13,180	94	0.7	286,100	3.6	5,000,000	63.0	E. W. Meckley, Asst. Engr.
6.0	126.0	114,200	3,600	3.15	18,400,000	24.5	52,000,000	69.0	Robt. L. Clemmitt, Asst. Water Engr.
.....	.....	2,357	1,984	84.1	930,000	.....	.....	....	Beloit Water, Gas & Electric Co.
3.0	60.0*	4,176	451	10.8	430,750	24.8	.....	....	A. N. Bennie.
0	261.0	.....	2	.....	.....	.....	1,150,000	46.0	G. H. Bryson.
2.5	76.0	1,000	940	94.0	306,800	66.8	30% Est.	30.0	
.....	309.0	81,062	4,004	4.94	41,400,000	29.8	.....	....	H. L. Lyons, Dep. Water Commr.
.....	131.5	3,211	3,247	100.0	.....	.....	.....	....	Western New York Water Co.
6.2	92.6	4,445	200	4.5	882,000	39.2	1,250,000	56.0	Frank Lawlor, Supt.
4.0	33.0	150,000	2,361	1.57	.....	.....	6,600,000	18.3	Arthur Perin.
0	68.6	6,000	6,000	100.0	.....	.....	.....	....	City Water Works.
.....	53.1	.....	4,200	.....	.....	.....	30%	30.0	W. E. Vest, Supt.
.....	259.0	1,600	.....	.....	.....	.....	2,500,000	74.0	R. D. Goodrich, City Engr.
9.0	218.0	277,000	16,969	6.1	118,000,000	22.8	.....	....	W. J. McCourt, Supt.
10.0	50.0	700	.....	.....	.....	.....	.....	....	C. J. Sullivan, Supt.
.....	158.0	2,700	40	1.5	1,000,000	39.5	50%	50.0	S. G. Highland, Secy. and Genl. Supt.
10.0	80.0	1,200	200	16.7	.....	.....	.....	....	S. J. Lowe, Supt.
4.0	83.3	2,753	2,721	99.0	1,240,000	100.0	200,000	16.0	Wm. O. Drake, Supt.
2.0	86.0	6,100	4,600	75.5	.....	.....	.....	....	S. L. Etnyre, Supt.
3.0	61.4	3,621	2,257	62.2	477,000	30.4	.....	....	A. W. W. & G. Co.
.....	88.8	640	355	55.5	.....	.....	.....	....	H. V. Gates, Dallas Water Co.
1.0	20.0*	478	478	100.0	118,550	91.2	96,000	74.0	Geo. A. Main, Supt.
5.0	117.6	2,100	1,056	50.4	.....	.....	50%	50.0	C. W. Wiles, Supt.
.....	197.0	44,500	300	0.67	3,750,000	.....	.....	....	C. F. Catchpole, Asst. Genl. Mgr.
.....	106.5*	10,900	7,525	69.0	.....	.....	.....	....	E. W. Kelly, Engr.
5.0	106.6	700	687	98.4	166,360	46.5	119,280	33.3	Chester & Fleming, Engrs.
.....	115.0	8,073	3,902	48.4	1,690,000	28.2	2,000,000	33.0	F. D. Hill, G. M.
3.0	121.1	3,650	3,650	100.0	1,577,714	81.4	743,000	38.3	J. B. Daly, Ch. Clerk.
0	218.0	17,433	535	3.0	4,680,000	29.8	11,050,000	70.4	E. W. Humphreys.
3.0	178.0	10,000	50	0.5	.....	.....	6,500,000	66.4	W. H. Durbin, Gen. Mgr.
10.0	76.1	750	30	4.0	.....	.....	.....	....	F. E. Forristel, Supt.
.....	111.0	5,489	213	3.9	1,063,000	34.2	2,000,000	64.4	

Col. 32 = $\frac{\text{Col. 9} - \text{Col. 21}}{\text{Col. 8}}$ Col. 33 = $\frac{\text{Col. 19}}{5}$

Note:
Col. 32 is correct only when Non Domestic Consumption is fully metered.
Col. 33 is correct assuming 5 persons per meter.
Note:
(A)—Metered houses, with two families or more, are classed as commercial.
* Includes commercial.

CITY	METERED DOMESTIC USE			NON-DOMESTIC CONSUMPTION				
				Total			Industrial	
	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration
	17	18	19	20	21	22	23	24
Akron, Ohio								
Albany, N. Y.								
Altoona, Pa	396	61,200	154.5	284	716,000	2,520	27	334,000
Appleton, Wis.	572			83			10	
Ashland, Wis.	283	109,000	385.0	272	337,000	1,240	41	276,000
Auburn, N. Y.	0			750	1,453,000	1,937	115	732,000
Augusta, Me.								
Allentown, Pa.	13	7,100	546.0	81	279,000	3,444	37	191,000
Baltimore, Md.								
Beloit, Wis.	1,636	190,000	116.0	348	740,000	2,126	13	572,000
Biddeford and Saco, Me.	329	95,400	290.0	122	335,350	2,749	34	280,000
Brockville, Ont.								
Brunswick, Me.	854	95,800	112.0	86	211,000	2,453	10	186,000
Buffalo, N. Y.				4,004	41,400,000	10,340		
Buffalo (Suburbs), N. Y.	3,154	439,000	139.0	93	4,930,000	53,000	93	4,930,000
Burlington, Ia.				200	882,000	4,410		
Calcutta, India								
Cedar Rapids, Ia.								
Charlotte, N. C.								
Cheyenne, Wyo.								
Chicago, Ill.								
Chisholm, Minn.								
Clarksburg, W. Va.				40	1,000,000	25,000	40	1,000,000
Clarksville, Tenn.								
Corning, N. Y.	2,432	862,000	354.0	289	378,000	1,305	24	250,000
Council Bluffs, Ia.								
Clinton, Ia.	1,683(a)	131,000(a)	78.0	574(a)	346,000(a)	603	63	157,000
Dallas, Ore.				24			8	
Daytona, Fla.	410	66,800	163.0	68	51,750	760	59	45,500
Delaware, Ohio								
Denver, Colo.				300	3,750,000	1,250	251	1,538,000
Duluth, Minn.								
Edgeworth Water Co.	670	86,700	129.0	17	79,660	4,690	9	74,300
Elmira, N. Y.	3,857	650,000	169.0	45	1,040,000	23,100	45	1,040,000
Elyria, Ohio*	3,438	620,414	181.0		957,300		33	752,400
Erie, Pa.				535	4,680,000	8,750	535	4,680,000
Evansville, Ind.								
Eveleth, Minn.	0	0	0	17	255,800	15,000		
Everett, Wash.								

John N. Chester
Alexander Potter
H. J. Montoulieu

W. S. Cramer
E. E. Davis
E. S. Cole,
Chairman.

NON-DOMESTIC CONSUMPTION							DOMESTIC PER CAPITA		OFFICIAL REPORTING
Industrial	Commercial			Public					
Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter			
25	26	27	28	29	30	31	32	33	
									H. H. Frost, Supt.
									J. B. Kilbourn, Supt.
12,370	257	382,000	1,486				24.0	31.0	C. B. Campbell, Secy.
	73								C. H. Vinal, Supt.
6,732	215			16	61,200	3,825	78.0	77.0	Sam Wheeler, Supt.
6,360	584	456,500	781	51	264,500	5,188	140.0		J. Walter Ackerman, Engr.
									W. B. Getchell.
5,102	44	88,600	2,014				137.0	109.0	E. W. Meckley, Asst. Engr.
									Robt. L. Clemmitt, Asst. Water Engr.
44,000	305	94,900	311	30	73,100	2,436		23.0	Beloit Water, Gas & Electric Co.
8,235	63	42,600	677	25	12,750	510	41.*	58.0	A. N. Bennie.
									G. H. Bryson.
18,600	76	25,000	329				41.0	22.0	
	4 004	41,400,000	10,340				217.0		H. L. Lyons, Dep. Water Commr.
53,000							33.0	28.0	Western New York Water Co.
							56.0		Frank Lawlor, Supt.
									Arthur Perin.
									City Water Works.
									W. E. Vest, Supt.
									R. D. Goodrich, City Engr.
									W. J. McCourt, Supt.
		30,000							C. J. Sullivan, Supt.
25,000							96.0		S. G. Highland, Secy and Genl. Supt.
									S. J. Lowe, Supt.
10,420	252	108,500	430	13	22,250	1,712	58.0	71.0	Wm. O. Drake, Supt.
									S. L. Etnyre, Supt.
2,492	472(a)	119,000(a)	252	39	70,000	1,794	48.0	16.0	A. W. W. & G. Co.
	12			4					H. V. Gates, Dallas Water Co.
7,700	—Included in Industrial.			9	6,270	697	12.0*	33.0	Geo. A. Main, Supt.
									C. W. Wiles, Supt.
6,130	0	0	0	49	2,212,000	45,140	180.0		C. F. Catchpole, Asst. Genl. Mgr.
									E. W. Kelly, Engr.
8,255	3	1,100	370	5	4,250	850	83.0	26.0	Chester & Fleming, Engrs.
23,100							95.0	34.0	F. D. Hill, G. M.
22,800	179	115,800	647		89,100		61.3	36.0	J. B. Daly, Ch. Clerk.
8,750							153.0		E. W. Humphreys.
									W. H. Durbin, Gen. Mgr.
				17	255,800	15,000	44.0		F. E. Forristel, Supt.

CITY	MUNICIPAL OR PRIVATE	PUMPED OR GRAVITY	AREA SQ. MI.	MILES OF MAINS	RANGE OF PRESSURES	RANGE OF ELEVATIONS	POPULATION	GALLONS DAILY CONSUMPTION
1	2	3	4	5	6	7	8	9
Fargo, N. D.	M	P	3.0	36.0	40–100	895–905	16,000	2,191,800
Fort Dodge, Ia.	M	P	4.0	26.0	35–110	0–150	20,000	1,000,000
Fort Smith, Ark.	M	P	.....	50.5	45–150	.....	28,000	2,531,000
Fall River, Mass.	M	P	.....	118.0	80	129	115,400	5,334,000
Galt, Ont.	M	P	4.0	36.0	90–120	0–200	12,000	1,000,000
Gloversville, N. Y.	M	G	.....	39.88	45–135	.....	20,000	1,340,000
Grand Rapids, Mich.	M	P	17.5	203.0	15–105	5–200	90,000	15,832,500
Green Bay, Wis.	P	P	.....	56.0	40–100	.....	27,000	1,204,000
Hagerstown, Md.	P	G	10.0	53.0	26–58	552–620	20,000	2,444,800
Harrisburg, Pa.	M	P	.....	91.0	30–84	310–430 L. S. 430–520 H. S.	70,000	8,390,600
Harvey, Ill.	.....	.....	2.25	18.0	40–90	Level	7,227	407,000
Holyoke, Mass.	M	G	23.0	92.67	65–105	60–380	60,000	6,780,000
Hollywood*	P	P	15.0	215.0	25–120	100–650	40,000	4,400,000
Hoquiam, Wash.	P	P	3.0	32.0	85–105	11–200	12,000	2,080,000
Havana, Cuba	M	P & G	12.0	250.0	15–45	0–250	400,000	55,000,000
Iron Mountain, Mich.	M	P	3.0	20.0	60–110	.....	10,000	526,000
Jacksonville, Fla.	M	P	.....	59.56	40–62.5	0–37	81,000	5,675,292
Jefferson City, Mo.	P	P	1.48	19.71	19–120	121–300	13,500	1,335,000
Jersey City, N. J.	M	G	29.2	225.0	25–70	1–70	300,000	44,000,000
Kokomo, Ind.	P	P	8.26	45.12	50–100	.....	20,000	1,950,000
Keokuk, Ia.	P	P	4.875	30.62	50–130	.....	14,000	1,468,000
Kalamazoo, Mich.	M	P	9.0	82.0	45–65	0–100	40,000	2,202,500
Kansas City, Mo.	M	P	60.0	542.0	30–150	22–300	280,000	32,973,000
La Grange, Ill.	.....	P	2.0	70.0	40–90	Level	10,500	576,000
Lake Charles, La.	P	.....	5.0	13.0	30–125	3–15	15,000	.....
Lancaster, Pa.	M	P	4.0	70.0	25–80	.....	60,000	7,247,000
Lincoln, Ill.	M	P	3.0	22.0	36–51	20–46	7,300	651,138
Litchfield, Ill.	P	P	3.5	8.0	30–80	25–125	7,000	.....
Los Angeles, Cal.	M	P & G	107.6	872.6	20–130	160–870	516,300	51,700,000
Louisville, Ky.	P	P	25.0	387.36	40–75	450–550	214,000	25,545,246
Louisiana, Mo.	P	P	1.74	10.03	95–140	.....	4,860	475,000
Lexington, Ky.	P	P	6.0	76.0	40–120	928–1019	40,000	2,483,742
Macon, Ga.	M	P	8.3	81.76	10–107	300–512	42,500	4,885,000
Madison, Wis.	M	P	4.0	75.96	50–85	0–125	27,000	2,127,000
Manchester, Vt.	P	.....	3.0	12.0	65–125	.....	1,500	64,000
Memphis, Tenn.	M	P	22.0	258.0	45–60	216–321	175,000	14,500,000
Marinette, Wis.	P	P	4.84	35.60	40–110	.....	14,610	1,363,270
Meridian, Miss.	M	P	.....	46.0	70–150	10–120	22,240	2,224,000
Merrill, Wis.	P	P	3.88	20.04	40–90	.....	8,689	908,220
Manila, P. I.	M	G	16.0	116.0	30–40	5–15	265,000	13,500,000

COMMITTEE—1914—*Continued*

PER CENT ALLOWED PUMP SLIP	PER CAPITA DAILY	TOTAL TAPS	TOTAL METERS	PER CENT METERS	GALLONS PER DAY METERED REGISTRATION	PER CENT	MINIMUM NIGHT RATE	PER CENT OF DAY RATE	OFFICIAL REPORTING
10	11	12	13	14	15	15*A*	16	16*A*	
5.0	137.0	2,400	150	6.3	.....	.....	.....	.....	F. L. Anders, City Engr.
5.0	50.0	2,600	2,500	96.0	548,000	54.8	300,000	30.0	John W. Proy.
0	90.4	4,500	1,200	26.6	786,800	31.0	.....	.....	W. H. Bruce, Supt.
.....	46.2	9,505	9,289	97.8	4,219,000	79.0	.....	.....	J. J. Kirby, W. Registrar.
0	83.3	3,000	1,200	40.0	.....	.....	83,000	8.3	Scott Bartleman, Supt.
.....	67.0	3,966	3,630	91.5	.....	.....	.....	.....	
0	176.0	21,121	9,870	46.7	6,668,300	42.1	6,177,600	39.0	L. D. Cutcheon, Sec. Mgr.
0	45.0	4,745	3,500	73.8	.....	.....	.....	.....	J. P. Flatley, Supt.
.....	122.2	4,364	526	12.1	1,483,000	60.7	1,000,000	41.0	Albert Heard, Genl. Mgr.
3.0	120.0	17,579	11,544	65.5	.....	.....	.....	.....	E. B. Showell, Jr., Chem. & Bact.
.....	56.2	1,115	1,109	99.5	279,500	68.7	360,000	88.4	
.....	113.0	4,500	429	9.5	1,932,000	28.5	3,540,000	52.2	Patrick Gear, Supt.
.....	110.0	9,102	9,102	100.0	2,950,000	67.1	.....	.....	O. E. Wern, Sec.
6.0	173.0	1,950	400	20.5	.....	.....	.....	.....	Harry C. Heermans, Pres.
.....	137.5	25,250	178	0.7	1,077,500	1.96	44,000,000	80.0	H. J. Montoulieu, Ch. Engr.
10.0	52.0	1,505	683	45.0	201,420	38.4	210,400	40.0	E. A. Croll, Supt.
4.0	70.0	10,111	7,828	77.4	.....	.....	3,720,000	65.5	L. E. Murphy, Supt.
5.0	99.0	1,387	477	34.4	870,820	65.2	475,000	35.7	L. B. Landman.
.....	146.7	35,100	5,100	14.5	18,062,000	41.0	8,000,000	18.2	F. McCarren, Assessor.
3.0	97.5	3,831	329	8.6	323,000	16.6	.....	.....	A. W. W. & G. Co.
3.0	105.0	2,718	1,753	64.5	377,500	25.7	.....	.....	A. W. W. & G. Co.
2.0	55.0	.....	.....	.....	.....	.....	1,200,000	54.5	H. A. Watson, Supt.
5.0	122.0	53,783	30,718	57.0	21,900,000	66.0	.....	.....	S. Y. High, Supt.
.....	54.9	1,373	1,369	99.6	435,000	75.6	480,000	83.4	
.....	.....	700	16	2.3	.....	.....	.....	.....	F. V. Gallaugher.
.....	121.0	13,000	4,500	34.6	2,600,000	35.8	2,500,000	34.5	John T. Brainard, Secy.
5.0	89.2	1,351	575	42.6	.....	.....	.....	.....	E. MacDonald.
.....	.....	272	30	11.0	.....	.....	.....	.....	David Davis, Mayor.
.....	136.1	74,361	58,000	77.9	.....	.....	.....	.....	Wm. Mulholland, Ch. Engr.
0	119.3	39,361	4,312	11.0	10,782,470	42.2	12,000,000	47.0	Theo A. Leisen, Ch. Engr. and Supt.
3.0	97.7	827	131	15.8	118,100	24.9	.....	.....	A. W. W. & G. Co.
4.0	62.1	5,206	5,206	100.0	2,370,000	95.35	1,050,000	42.5	W. S. Cramer, Ch. Engr.
9.8	115.0	6,475	3,495	54.0	1,660,800	34.0	1,690,000	34.6	Cliff T. Williamson.
0	79.0	5,775	5,733	99.2	1,348,587	63.4	300,000	14.1	E. E. Parker, Supt.
.....	43.0	392	271	69.0	56,650	88.5	.....	.....	A. B. Marsden, Treas. and Mgr.
.....	83.0	24,000	14,084	58.7	2,440,000	16.8	8,000,000	55.0	W. S. Wills, Genl. Supt.
3.0	93.3	2,815	114	4.1	126,224	9.2	.....	.....	A. W. W. & G. Co.
0	100.0	3,672	2,560	70.0	.....	.....	756,160	34.0	M. L. Worrett.
3.0	104.5	1,054	.....	.....	.....	.....	.....	.....	A. W. W. & G. Co.
.....	51.0	7,000	6,700	96.0	7,500,000	55.5	4,500,000	33.0	A. Gideau, Ch. Engr.

CITY	METERED DOMESTIC USE			NON-DOMESTIC CONSUMPTION				
				Total			* Industrial	
	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration
	17	18	19	20	21	22	23	24
Fargo, N. D.								
Fort Dodge, Ia.	2,450	392,000	160.0	50	156,000	3,120	50	156,000
Fort Smith, Ark.	806	91,600	114.0	271	695,200	2,566	30	145,700
Fall River, Mass.	.....	2,075,000	.....	.....	2,144,000	.....	.....	784,000
Galt, Ont.								
Gloversville, N. Y.	3,630	1,340,000	369.0					
Grand Rapids, Mich.	9,058	2,325,000	256.0	812	4,343,300	5,349	742	4,311,000
Green Bay, Wis.								
Hagerstown, Md.	0	0	0	526	1,483,000	2,820	.....	1,220,000
Harrisburg, Pa.								
Harvey, Ill.								
Holyoke, Mass.	27	52,600	1948	402	1,879,400	4,675	193	963,000
Hollywood	9,102	2,950,000	.....					
Hoquiam, Wash.								
Havana, Cuba	.....	.....	.....	178	1,077,500	6,050	178	1,077,500
Iron Mountain, Mich.	635	.....	.....	48	.....	.....	.....	.....
Jacksonville, Fla.								
Jefferson City, Mo.	315	46,410	147.0	162	824,420	5,090	22	716,400
Jersey City, N. J.	2,200	3,300,000	1500	2,900	14,362,000	4,950	1,718	13,007,000
Kokomo, Ind.	190	22,900	121.0	139	300,100	2,160	60	224,000
Keokuk, Ia.	1,373(a)	106,500(a)	77.6	380(a)	271,000(a)	713	31	146,500
Kalamazoo, Mich.								
Kansas City, Mo.								
La Grange, Ill.								
Lake Charles, La.								
Lancaster, Pa.								
Lincoln, Ill.								
Litchfield, Ill.								
Los Angeles, Cal.								
Louisville, Ky.	1,465	721,537	493.0	2,847	10,060,000	3,538	.....	.....
Louisiana, Mo.	70	6,300	90.0	61	111,800	1,833	11	95,600
Lexington, Ky.	.....	676,000	.....	.....	1,695,000	.....	.....	716,000
Macon, Ga.	3,442	356,800	103.6	53	1,304,000	24,600	.....	.....
Madison, Wis.	5,050	945,000	187.0	683	413,587	605.5	79	157,087
Manchester, Vt.	254	36,105	142.0	19	20,550	1,081	4	14,213
Memphis, Tenn.	13,263	1,920,000	145.0	510	520,000	1,020	.....	276,000
Marinette, Wis.	10	664	66.0	104	125,560	1,207	35	85,000
Meridian, Miss.								
Merrill, Wis.	24	1,800	75.0	13	7,917	609	.....	2,923
Manila, P. I.								

NON-DOMESTIC CONSUMPTION							DOMESTIC PER CAPITA		OFFICIAL REPORTING
Industrial	Commercial			Public					
Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter			
25	26	27	28	29	30	31	32	33	
									F. L. Anders, City Engr.
3,120							42.0	32.0	John W. Proy.
4,855	215	480,000	2,233	26	69,500	2,673	66.0	23.0	W. H. Bruce, Supt.
	Included in Domestic				1,360,000		27.6		J. J. Kirby, W. Registrar.
									Scott Bartleman, Supt.
							67.0	74.0	
5,810				70	32,300	462	127.6	51.2	L. D. Cutcheon, Sec. Mgr.
									J. P. Flatley, Supt.
		263,000					48.0		Albert Heard, Genl. Mgr.
									E. B. Showell, Jr., Chem. & Bact.
4,990	139	694,000	4,990	70	222,400	3,177	82.0		Patrick Gear, Supt.
									O. E. Wern, Secy.
									Harry C. Heermans, Pres.
6,050							135.0		H. J. Montoulieu, Ch. Engr.
				16					E. A. Croll, Supt.
									L. E. Murphy, Supt.
32,560	121	54,220	448	19	53,780	2,830	37.8	29.4	L. B. Landman.
7,570	1,100	55,000	500	82	1,205,000	14,700	98.8		F. McCarren, Assessor.
3,733	60	51,300	8,550	13	24,800	1,907	82.5	24.0	A. W. W. & G. Co.
4,726	336(a)	102,800(a)	306	13	16,700	1,285		15.5	A. W. W. & G. Co.
									H. A. Watson, Supt.
									S. Y. High, Supt.
									F. V. Gallaugher.
									John T. Brainard, Secy.
									E. MacDonald.
									David Davis, Mayor.
									Wm. Mulholland, Ch. Engr.
							72.3	98.6	Theo. A. Leisen, Ch. Engr. and Supt.
8,691	47	8,180	174	3	8,020	2,673	75.0	18.0	A. W. W. & G. Co.
		642,000			337,000		19.7		W. S. Cramer, Ch. Engr.
							84.3	20.7	Cliff T. Williamson.
1,988	561	167,250	298	43	89,250	2,076	63.0	37.4	E. E. Parker, Supt.
3,554	8	3,630	454	7	2,707	387	28.9	28.4	A. B. Marsden, Treas. and Mgr.
					244,000		80.0	29.0	W. S. Wills, Genl. Supt.
2,430	63	35,770	568	6	4,710	785	85.0	13.0	A. W. W. & G. Co.
									M. L. Worrett.
		1,470		4	3,514	880	103.6	15.0	A. W. W. & G. Co.
									A. Gideau, Ch. Engr.

CITY	MUNICIPAL OR PRIVATE	PUMPED OR GRAVITY	AREA SQ. MI.	MILES OF MAINS	RANGE OF PRESSURES	RANGE OF ELEVATIONS	POPULATION	GALLONS DAILY CONSUMPTION
1	2	3	4	5	6	7	8	9
Miles City, Mont.	M	P	0.75	18.5	50–130	0–2350	6,000	850,000
Milwaukee, Wis.	M	P	25.69	505.0	15–75	10–180	430,000	47,920,000
Monroe, Wis.	M	P	1.5	9.5	30–75	50–115	3,000	238,000
Mount Vernon, Ind.	P	P	2.78	15.38	80–110	.....	5,800	735,616
Muncie, Ind.	P	P	11.5	57.1	35–90	.....	30,000	2,915,272
New York City, N. Y.	M & P	P & G	181.3	2793.0	10–140	0–409	4,915,000	462,900,000
New Albany, Ind.	P	P	3.0	45.0	75–80	25–275	25,000	2,000,000
New Castle, N. S. Wales.	M	P	.....	.....	0–100	0–300	101,000	2,835,000
New Castle, Pa.	P	P	13.2	77.60	80–160	800–1150	36,000	3,536,000
New Orleans, La.	M	P	17.0	550.0	60–70	0–15	360,000	20,600,000
Norwich, N. Y.	P	G	3.0	19.6	40–60	0–50	8,000	2,225,000
Oak Park, Ill.	M	P	4.5	80.0	50–50	Level	26,000	1,790,000
Ogdensburg, N. Y.	M	P	6.0	35.0	5–50	245–325	18,000	2,500,000
Omaha, Neb.	M	P	28.0	274.0	20–135	0–290	170,000	18,990,692
Providence, R. I.	M	P	18.28	402.0	26–97	6–200	267,000	17,680,667
Passaic, N. J.	P	G	7.4	73.5	44–100	10–158	75,900	4,710,000
Pine Bluffs, Ark.	P	G	4.13	36.0	45–100	.....	16,000	1,145,000
Philadelphia, Pa.	M	P	65.0	1754.0	20–150	0–400	1,611,000	289,671,000
Plattsmouth, Neb.	P	P	4.0	10.0	40–90	120–233	2,700	244,500
Port Arthur, Ont.	M	P	2.5	38.0	70–114	617–814	18,000	2,612,500
Portsmouth, Va.	P	P	17.7	143.86	40	.....	75,000	4,867,486
Quincy, Ill.	P	P	4.5	67.5	3–110	100–330	38,587	1,923,300
Racine, Wis.	P	P	8.35	74.59	65–110	.....	41,000	3,444,900
Rahway, N. J.	M	P	2.5	23.75	45–48	0–30	10,000	1,827,000
Rensselaer, N. Y.	P	P	2.0	20.0	50–120	10–200	11,000	1,540,000
Reno and Sparks, Nev.	M	G	8.0	57.5	50–90	4500–4600	13,500	9,460,800
Richmond, Ind.	P	P	4–5	48.0	40–110	.....	23,000	2,615,175
Richmond, Va.	M	P	7.5	163.0	10–86	6–210	120,000	13,861,245
Ripan, Wis.	P	P	1.5	11.6	25–90	35–160	3,800	289,700
Rochester, N. Y.	M	G	22.0	460.0	30–80	425–615	250,000	23,740,000
Rochester & Lake Ont. W. Co.	P	P	9.5	80.21	40–225	250–660	.....	3,890,000
Rockford, Ill.	M	P	9.6	112.67	20–65	97–213	53,000	2,865,836
Scottdale, Pa.	P	P & G	6.0	35.1	25–100	1020–1140	8,500	2,074,000
Saginaw, Mich.	M	P	.....	117.0	45–90	0–30	29,600	9,878,000
St. Boniface, Man.	M	P	17.2	24.5	56–64	685–703	14,500	355,200
St. Catherine, Ont.	M	G	5.0	55.0	73–116	266–366	17,000	2,740,000
St. Joseph, Mo.	P	P	23.3	147.2	90–110	.....	89,403	9,000,000
St. Louis, Mo.	M	P	61.37	962.0	35–125	15–180	730,000	82,100,000
Salt Lake City, Utah.	M	G	49.6	227.0	65–198	4250–5000	100,000	18,616,525
San Diego, Cal.	M	G	38.0	325.93	50–150	0–420	85,000	6,853,863

COMMITTEE—1914—*Continued*

PER CENT ALLOWED PUMP SLIP	PER CAPITA DAILY	TOTAL TAPS	TOTAL METERS	PER CENT METERS	GALLONS PER DAY METERED REGISTRATION	PER CENT	MINIMUM NIGHT RATE	PER CENT OF DAY RATE	OFFICIAL REPORTING
10	11	12	13	14	15	15*A*	16	16*A*	
.....	142.0	750	650	86.6	.....	.....	.....	....	G. C. Pruth.
0	111.4	59,603	59,233	99.4	34,800,000	72.6	30,000,000	62.5	H. P. Bohman, Supt.
10.0	79.0	563	581	100.0	216,500	91.0	133,320	56.0	M. J. Gettings, Supt.
3.0	126.8	1,172	106	9.0	111,525	15.2	.....	....	A. W. W. & G. Co.
3.0	97.2	3,742	887	23.8	774,583	26.5	.....	....	A. W. W. &. G. Co.
5.0±	94.2	364,800	95,200	26.1	129,700,000	28.0	.....	....	I. M. de Varona, Ch. Engr.
10.0	80.0	4,000	351	8.8	.....	.....	.....	....	J. O. Emdris, Jr., Supt.
5.0	28.0	18,405	3,093	16.8	.....	.....	.....	....	
3.0	98.2	7,753	6,017	77.7	1,591,200	45.0	.....	....	A. W. W. & G. Co.
.....	57.2	40,200	40,100	99.7	11,800,000	57.3	.....	....	G. G. Earl, Genl. Supt.
.....	278.0	2,063	15	0.7	.....	.....	.....	....	J. M. Diven, Jr., Supt.
.....	69.0	5,750	5,750	100.0	1,690,000	94.4	800,000	44.5	H. P. T. Matte, Supt.
.....	138.9	3,000	6	0.2	.....	.....	1,750,000	70.0	H. A. Lord, Supt.
0	112.0	25,325	23,818	94.0	.....	.....	7,596,276	40.0	L. H. Marshall.
2.0	66.0	30,159	27,529	91.0	.....	.....	.....	....	
.....	62.0	7,920	4,808	60.7	2,515,000	53.2	2,600,000	55.2	W. C. Hopper, Supt.
10.0	71.6	2,267	2,267	100.0	316,600	27.6	960,000	83.8	Byron C. Fowles, Supt.
.....	179.7	350,000	16,000	4.6	.....	.....	200,000,000	69.2	C. E. Davis, Chief.
2.0	90.5	570	208	36.4	74,150	30.3	12,000	....	H. H. Sinclair, Supt.
.....	145.0	2,268	333	14.7	724,000	27.7	.....	....	
3.0	64.9	10,593	862	8.1	1,711,700	35.2	.....	....	A. W. W. & G. Co.
.....	50.0	5,838	3,725	63.8	1,323,600	68.8	.....	....	W. R. Gelston, Supt.
3.0	84.0	7,649	5,574	72.8	1,783,500	51.6	.....	....	A. W. W. & G. Co.
5.0	182.7	1,908	180	9.4	.....	.....	.....	....	A. F. Kerstein, Supt.
2.0	140.0	1,900	150	7.9	162,000	10.5	.....	....	R. S. Hinckley, Supt.
.....	701.0	2,300	0	0	0	0	.....	....	L. O. Murphy, Local Engr.
.....	113.7	5,038	3,267	65.0	1,549,000	59.0	.....	....	H. A. Dell, Treas.
.....	115.5	24,380	18,581	75.2	10,423,000	75.2	.....	....	E. E. Davis, Supt.
5.0	76.2	700	121	17.3	40,140	13.8	134,460	47.0	W. E. Haseltine, Ripan L. & W. Co.
.....	95.0	44,000	43,888	99.5	16,645,000	70.0	10,000,000	42.0	Beekman C. Little.
.....	.....	3,279	3,279	100.0	3,878,000	99.0	.....	....	Rochester & Lake Ontario Water Co.
4.33	54.0	9,305	8,652	93.0	1,643,300	57.4	.....	....	Oscar E. Bulkley.
0	244.0	2,135	75	3.5	506,000	24.4	300,000	14.5	G. S. Cheney, Supt.
0	333.7	8,350	343	4.1	920,900	9.3	.....	....	G. V. Chandler, Bookkeeper.
.....	24.5	.....	1,500	100.0	355,200	.....	.....	....	M. P. Blair, City Engr.
.....	161.0	4,857	153	3.15	848,000	31.0	.....	....	Alex D. Milne, Supt.
3.0	101.0	12,506	2,175	17.4	4,795,000	53.3	.....	...	
7.0	112.5	112,124	7,500	6.7	26,000,000	31.7	60,000,000	73.0	Edward E. Wall, Water Comm.
.....	186.2	18,529	1,214	6.5	5,162,077	27.7	7,633,000	41.0	Chas. F. Barrett, Supt.
.....	80.6	14,153	14,153	100.0	5,530,000	80.8	.....	....	

CITY	METERED DOMESTIC USE			NON-DOMESTIC CONSUMPTION				
				Total			Industrial	
	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration
	17	18	19	20	21	22	23	24
Miles City, Mont.								
Milwaukee, Wis.	40,629			59,233(a)	34,000,000(a)	574	15,500	18,300,000
Monroe, Wis.	562	100,000	178.0		116,500		13	95,500
Mount Vernon, Ind.	23	2,435	106.0	83	109,090	1,314	15	84,500
Muncie, Ind.	536	73,658	1372.0	351	700,925	1,997	55	496,325
New York City, N. Y.								
New Albany, Ind.								
New Castle, Pa.	5,321	501,200	94.0	696	1,090,000	1,565	74	838,300
New Orleans, La.	36,256	6,035,000	166.0	1,680	5,785,000	3,443	Included in Comm	
Norwich, N. Y.								
Oak Park, Ill.	5,700	1,362,600	239.0	50	327,400	6,548	10	221,300
Ogdensburg, N. Y.								
Omaha, Neb.								
Providence, R. I.								
Passaic, N. J.	4,700	1,198,000	255.0	108	1,317,000	12,190	94	1,280,000
Pine Bluffs, Ark.	1,963	197,400	100.6	250	119,200	476.8		
Philadelphia, Pa.								
Plattsmouth, Nev.				208	74,150	358		
Port Arthur, Ont.				280	724,000	2,586		
Portsmouth, Va.	33	4,700	143.0	829	1,707,000	2,060	134	1,491,000
Quincy, Ill.	2,893	414,500	143.0	832	909,100	1,093	136	623,300
Racine, Wis.	3,863	283,500	73.0	1,711	1,500,000	876	128	1,094,000
Rahway, N. J.								
Rensselaer, N. Y.								
Reno and Sparks, Neb.								
Richmond, Ind.		218,000			1,331,000			905,000
Richmond, Va.	16,597	1,782,166	107.4	1,984	8,640,833	4,355	783	3,865,760
Ripan, Wis.	79	5,540	70.0	42	34,600	824	9	16,460
Rochester, N. Y.	42,888	7,820,000	182.5	1,000	8,825,000	8,825	400	4,570,000
Rochester & Lake Ont. W. Co	3,147	520,000	165.0	132	3,358,000	25,420	132	3,300,000
Rockford, Ill.								
Scottdale, Pa.	20	10,800	540.0	55	495,200	9,000	30	477,900
Saginaw, Mich.	114	31,000	273.0	229	889,900	3,885	67	667,000
St. Boniface, Man.								
St. Catherine, Ont.				153	848,000	5,540	88	748,000
St. Joseph, Mo.	775	135,000	175.0	1,400	4,660,000	3,329	135	3,593,000
St. Louis, Mo.	1,945	2,191,694	1127.0	5,555	24,210,554	4,358	809	14,301,633
Salt Lake City, Utah	285	115,425	405.0	929			929*	5,046,652*
San Diego, Cal.	11,985	3,072,000	256.0	2,168	2,458,000	1,134	200	615,000

NON-DOMESTIC CONSUMPTION							DOMESTIC PER CAPITA		OFFICIAL REPORTING
Industrial	Commercial			Public					
Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter			
25	26	27	28	29	30	31	32	33	
									G. C. Pruth.
1,180	57,429(a)	14,100,000(a)	245.5	254	2,500,000	9,840	32.4		H. P. Bohman, Supt.
7,340							40.5	35.6	M. J. Gettings, Supt.
5,633	60	8,730	145	8	15,860	1,982	108.0	21.0	A. W. W. & G. Co.
9,024	282	187,300	664	14	17,300	1,240	73.8		A. W. W. &. G. Co.
									I. M. de Varona, Ch. Engr.
									J. O. Emdris, Jr., Supt.
11,324	602	225,000	374	20	26,700	1,335	68.0	19.0	A. W. W. & G. Co.
ercial.	1,277	4,620,000	3,617	403	1,145,000	2,841	41.0	0.33	G. G. Earl, Genl. Supt.
									J. M. Diven, Jr., Supt.
2,213	25	41,800	1,672	15	64,300	4,287	56.2	48.0	H. P. T. Matte, Supt.
									H. A. Lord, Supt.
									L. H. Marshall.
13,620				14	37,000	2,643	44.7	51.0	W. C. Hopper, Supt.
							64.0	20.0	Byron C. Fowles, Supt.
									C. E. Davis, Chief.
							63.0		H. H. Sinclair, Supt.
							105.0		
11,127	651	121,400	187	44	94,600	2,150	42.0	28.6	A. W. W. & G. Co.
4,583	637	209,400	329	59	76,400	1,295	26.0	28.6	W. R. Gelston, Supt.
8,545	1,541	315,000	204	42	91,000	2,166	47.0	15.0	A. W. W. & G. Co.
									A. F. Kerstein, Supt.
									R. S. Hinckley, Supt.
									L. O. Murphy, Local Engr.
		180,000			246,000				H. A. Dell, Treas.
4,937	1,114	3,290,000	2,953	87	1,485,133	17,071	43.5	21.5	E. E. Davis, Supt.
1,829	30	12,440	415	3	5,700	1,900	67.0	14.0	W. E. Haseltine, Ripan L. & W. Co.
11,425	450	3,050,000	6,777	150	1,205,000	8,040	59.7	36.5	Beekman C. Little.
25,000	—Included in Domestic.				58,000			33.0	Rochester & Lake Ontario Water Co.
					570,160				Oscar E. Bulkley.
15,930	10	10,600	1,060	15	6,700	447	185.7	108.0	G. S. Cheney, Supt.
9,955	162	222,900	1,376				304.0	55.0	G. V. Chandler, Bookkeeper.
									M. P. Blair, City Engr.
8,500	65	100,000	1,540				111.0		Alex D. Milne, Supt.
26,615	1,165	722,000	620	100	345,000	3,455	48.5	35.0	
17,678	4,515	8,844,434	1,959	231	1,064,489	4,608	79.0	225.0	Edward E. Wall, Water Comm.
5,432*				0				81.0	Chas. F. Barrett, Supt.
3,075	1,880	1,024,000	545	88	819,000 115,500 gals not metered	9,307	51.7	51.2	

CITY	MUNICIPAL OR PRIVATE	PUMPED OR GRAVITY	AREA SQ. MI.	MILES OF MAINS	RANGE OF PRESSURES	RANGE OF ELEVATIONS	POPULATION	GALLONS DAILY CONSUMPTION
1	2	3	4	5	6	7	8	9
San Lorenzo, Cal	P	P	4.0	20.9	65–90	100–200	2,000	648,000
Shamokin, Pa	M	G	19?	60.3	10–100	700–900	40,000	Not Measured
Spokane, Wash	M	P	39.25	367.22	30–165	1–710	104,402	29,869,000
Springfield, Mass	M	G	38.0	205.31	80–144	70–205	99,457	10,712,000
Stockton, Cal	P	P	10.0	74.0	40–50	1–10	30,000	4,138,132
Streator, Ill	P	P	5.5	46.0	40–110	0–42	14,000	1,840,000
Sunbury, Pa	P	P	2.0	40.0	25–100	0–80	15,000	3,424,663
Sydney, N. S. Wales	M	P & G	.....	1864.0	25–75	5–360	776,075	39,048,000
Tacoma, Wash	M	P & G	25.0	300.0	25–100	24–410	100,000	46,000,000
Tampa, Fla	P	P	7.5	77.5	40–110	0–55	65,000	4,365,000
Toledo, Ohio	M	P	27.0	280.0	30–75	0–20	185,000	18,457,844
Toronto, Ont	M	.....	.....	526.0	40–80	245–550	450,000	58,000,000
Troy, N. Y	M	G	7.0	115.4	30–140	26–405	70,000	20,000,000
Urban Water Supply Co	P	P	.....	5 0	70–80	50–75	.....	2,000,000
Utica, N. Y	P	G	15.0	182.0	40–100	400–650	95,000	7,480,000
Victoria, B. C	M	G	11.0	128.0	30–91	100–255	45,000	3,602,300
Walkerville, Ont	P	P	3½	24½	65–130	6–50	7,500	2,811,560
Washington, D. C	M	P & G	70.0	57.4	22–117	0–423	353,000	57,500,000
Waterloo, Ia	M	P	12.95	48.5	60–110	844–955	32,000	1,338,621
West St. Louis, Mo	P	P	.....	292.0	20–120	0–360	50,000	2,750,000
Wichita, Kan	P	P	14.45	132.59	65	.....	54,545	3,820,000
Wilkinsburg, Pa	P	P	12–15	150+	10–210	750–1300	80,000	8,567,000
Williamsport, Pa	P	P & G	10.5	87.61	30–65	21–88	40,000	6,000,000
Wilmington, Del	M	P	10.2	135.0	20–93	0–270	92,000	11,416,069
Wilmington, N. C	M	P	5.0	42.0	55–60	40–72	30,000	2,800,000
Woonsocket, R. I	M	P	.....	63.0	50–120	.....	47,500	1,529,000
Worcester, Mass	M	G	.....	258.0	85–150	481	160,000	11,115,953
Yarmouth, N. S	M	P	.....	30+	50–80	40–120	6,700	808,627
Yazoo City, Miss	M	P	5.0	14.4	5–110	100–341	6,796	500,000 +
Yonkers, N. Y	M	P	2.2	148.37	30–135	0–320	88,500	8,680,000
Yokohama, Japan	M	G	7.57	149.36	30–70	4–150	323,990	6,240,000

COMMITTEE—1914—*Concluded*

PER CENT ALLOWED PUMP SLIP	PER CAPITA DAILY	TOTAL TAPS	TOTAL METERS	PER CENT METERS	GALLONS PER DAY METERED REGISTRATION	PER CENT	MINIMUM NIGHT RATE	PER CENT OF DAY RATE	OFFICIAL REPORTING
10	11	12	13	14	15	15A	16	16A	
1-1½	324.0	800	12	1.5	.....	.....	.....	.....	Chas. M. Whiting, Secy.
.....	.....	6,800	60	0.9	444,000	.....	.....	.....	B. W. Haupt, Secy. Roaring Creek W. Co.
0	286.1	24,663	10,882	44.0	2,740,000	9.2	.....	.....	A. Lindsay, Supt.
.....	108.0	13,667	12,872	94.4	6,848,000	63.9	2,000,000	18.7	E. E. Lochridge.
4-10	137.9	5,915	665	11.2	757,184	18.3	1,680,000	40.5	J. W. Hall, Mgr. (Pac. Gas & Elec. Co.)
8.0	131.0	3,892	412	10.6	775,857	42.0	1,296,000	70.0	D. E. Hoggan, Supt.
0	228.0	2,374	64	2.7	1,945,000	56.8	1,250,000	36.5	Harry Landon, Supt.
.....	50.0	940,000	33,086	3.5	11,730,000	30.0	.....	.....	Charles W. Smith.
.....	460.0	15,688	1,824	11.6	.....	.....	.....	.....	Dr. Willis E. Everette.
3.1	67.0	6,903	1,621	23.5	1,165,000	26.7	3,312,000	75.9	
6.5	99.8	28,710	25,485	88.7	13,843,300	75.0	11,000,000	60.0	
.....	129.0	95,000	3,512	3.7	.....	.....	.....	.....	
.....	285.7	11,726	298	2.5	1,980,000	9.9	.....	.....	J. M. Diven, Supt.
4.0	.....	15	15	100.0	1,918,000	95.9	.....	.....	S. B. Severson, Maspeth, L. I.
.....	78.7	12,821	12,729	99.3	6,150,000	82.2	.....	.....	Don. R. Sidle.
.....	80.0	.....	9,200	.....	2,352,940	65.3	?4,636,800	.....	
3-15	375.0	1,200	100	8.3	1,291,070	46.0	1,308,000	46.5	Walkerville W. Co., C. D. Brown, Secy.-Treas.
3.76	162.7	66,478	39,184	58.9	17,727,000	30.8	42,529,000	74.0	W. A. McFarland, Supt.
6.0	41.8	4,520	4,313	95.4	875,000	65.4	450,520	34.0	G. E. Shoemaker, Secy.
0	55.0	5,870	3,601	61.4	.....	.....	.....	.....	
3.0	70.0	7,092	3,083	43.5	850,000	22.2	.....	.....	
2.0	107.0	12,706	12,575	99.0	6,991,000	81.5	.....	.....	W. C. Hawley, Ch. Engr. Pa. W. Co.
.....	150.0	7,125	100	1.4	1,255,404	20.9	.....	.....	Williamsport Water Co.
.....	124.0	19,909	8,695	43.7	6,382,082	55.9	2,000,000	17.5	Edgar M. Hoopes, Jr.
.....	93.3	4,500	1,442	32 0	.....	.....	.....	.....	W. E. Merritt, Supt.
.....	32.2	3,625	3,466	95.6	1,315,000	86.0	445,210	29.1	Arthur F. Ballou, Supt.
.....	69.5	18,650	18,276	98.0	7,880,000	70.8	.....	.....	Geo. W. Bachelder, Commr.
10.0	120.7	3,674	4	0.10	14,310	1.8	.....	.....	Geo. H. Rohnston, Supt.
3.0	73.6	1,248	1,048	84.1	.....	.....	.....	.....	James G. Butler, Supt.
0	98.1	8,964	9,921	100.0	5,438,000	62.6	.....	.....	E. L. Peene, Supt.
.....	19.3	25,155	2,295	9.1	.....	.....	(?)31,221	.....	S. Inone, Ch. Engr.

CITY	METERED DOMESTIC USE			NON-DOMESTIC CONSUMPTION				
				Total			Industrial	
	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration
	17	18	19	20	21	22	23	24
San Lorenzo, Cal				9			4	
Shamokin, Pa				60	444,000			
Spokane, Wash	300	656,000	2186	88	2,084,000	23,680	13	408,000
Springfield, Mass								
Stockton, Cal								
Streator, Ill	268	139,000	518.5	144	637,000	4,425	111	583,000
Sunbury, Pa				64	1,945,000	30,400	24	1,885,000
Sydney, N. S. Wales								
Tacoma, Wash	20			1,361			100	
Tampa, Fla								
Toledo, Ohio	24,803	5,538,000	223.2				682*	8,305,300*
Toronto, Ont								
Troy, N. Y							298	1,980,000
Urban Water Supply Co	8	274	34.0	7	1,918,000	274,000	6	1,918,000
Utica, N. Y	12,379	1,968,000	159.0	350	4,190,000	11,950	300*	3,985,000
Victoria, B. C	7,909	966,600	122.0				797*	1,303,540*
Walkerville, Ont				100	1,393,539	12,910	100	1,230,000
Washington, D. C	20,565	3,885,000	189.0	3,113	13,842,000	4,440	230	6,290,000
Waterloo, Ia	3,700	365,263	98.7	613	509,710	831	547	417,900*
West St. Louis, Mo								
Wichita, Kan	2,259	235,000	104.0	824	615,000	746	30	117,700
Wilkinsburg, Pa		2,036,000			4,955,000			4,765,000*
Williamsport, Pa	0	0	0	100	1,225,404	12,254	100	1,225,404
Wilmington, Del	8,437	2,107,434	250.0				258	4,274,648
Wilmington, N. C								
Woonsocket, R. I								
Worcester, Mass		2,985,000						2,492,000
Yarmouth, N. S								
Yazoo City, Miss	215	30,500	142.0					
Yonkers, N. Y	9,051	2,400,000	265.0				170	3,038,000
Yokohama, Japan								

NOTE—* Includes commercial.

COMMITTEE—1914—*Concluded*

NON-DOMESTIC CONSUMPTION							DOMESTIC PER CAPITA		OFFICIAL REPORTING
Industrial	Commercial			Public					
Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter	No. Meters	Gallons Daily Registration	Gallons per Day per Meter			
25	26	27	28	29	30	31	32	33	
.....	1	.....	.....	4	.....	.....	.....	.....	Chas. M. Whiting, Secy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	B. W. Haupt, Secy. Roaring Creek W. Co.
31,400	50	180,000	3,600	25	1,496,000	59,840	266.0	437.0	A. Lindsay, Supt.
.....	.....	.....	.....	.....	.....	.....	.....	.....	E. E. Lochridge.
.....	.....	.....	.....	.....	364,380	.....	.....	.....	J. W. Hall, Mgr. (Pac. Gas & Elec. Co.)
5,252	.....	.....	.....	33	54,000	1,636	86.0	104.0	D. E. Hoggan, Supt.
78,541	40	60,000	1,500	0	.....	.....	98.6	.....	Harry Landon, Supt.
.....	.....	.....	.....	.....	.....	.....	.....	.....	Charles W. Smith.
.....	1,193	.....	.....	68	.....	.....	.....	.....	Dr. Willis E. Everette.
.....	.....	.....	.....	.....	49,250	.....	.....	.....	
12,180*	.....	.....	.....	.....	.....	.....	.....	45.0	
.....	.....	.....	.....	.....	.....	.....	.....	.....	
6,644	.....	.....	.....	.....	.....	.....	.....	.....	J. M. Diven, Supt.
319,667	1	55	55	.....	.....	.....	.....	7.0	S. B. Severson, Maspeth, L. I.
13,283	.....	.....	.....	50	205,000	41,000	34.6	32.0	Don. R. Sidle.
1,635*	.....	.....	.....	70	82,800	1,183	189.0	24.0	
12,300	Meters not used on Commercial.			.....	61,070	.....	.....	.....	Walkerville W. Co., C. D. Brown, Secy.-Treas.
27,348	2,654	6,632,000	2,500	229	920,000	4,017	123.6	38.0	W. A. McFarland, Supt.
764	.....	.....	.....	66	91,810	1,391	26.0	20.0	G. E. Shoemaker, Secy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	
3,923	761	426,000	560	33	71,300	2,162	58.8	21.0	
.....	.....	.....	.....	.....	190,000	.....	45.0	.....	W. C. Hawley, Ch. Engr. Pa. W. Co.
12,254	.....	.....	.....	.....	.....	.....	119.0	.....	Williamsport Water Co.
16,568	.....	.....	.....	.....	.....	.....	.....	50.0	Edgar M. Hoopes, Jr.
.....	.....	.....	.....	.....	.....	.....	.....	.....	W. E. Merritt, Supt.
.....	.....	.....	.....	.....	.....	.....	.....	.....	Arthur F. Ballou, Supt.
.....	—Included in industrial.			.....	946,000	.....	17.9	.....	Geo. W. Bachelder, Commr.
.....	.....	.....	.....	.....	.....	.....	.....	.....	Geo. H. Rohnston, Supt.
.....	.....	.....	.....	.....	.....	.....	.....	28.0	James G. Butler, Supt.
17,870	.....	.....	.....	.....	.....	.....	.....	53.0	E. L. Peene, Supt.
.....	.....	.....	.....	.....	.....	.....	.....	.....	S. Inone, Ch. Engr.

DRY FEED OF CHEMICALS IN WATER PURIFICATION

By W. F. Monfort

Dry feeding of chemicals has been practiced in American plants to a considerable extent for more than ten years. At St. Louis in 1903 and 1904 the advantage of avoiding bulky solutions of iron sulphate and milk of lime was appreciated and the method adopted by which the chemicals were dumped at five minute intervals into dissolving (or slaking) tanks and the solution or suspension applied to the influent water without further control. Later (1908) this method was modified by the use of clock operated automatic scales for lime, and a modified orifice feed for iron sulphate. The latter consists of a vertical orifice discharging upon a cylindrical drum revolving at a constant speed. Under test conditions with crushed and screened material its operation was satisfactory and its error small.

At Lancaster, Pennsylvania, a device was introduced which is thus referred to in *Engineering Record*, September, 1907.

> Originally designed for softening and coagulation with lime and soda ash, it was decided to make no change in hardness of the water, but to use alum and soda as dry powders which are thrown into the water by a distributing device actuated by a Poncelot undershot wheel operated by the water as it flows into the coagulating basin.

This was an adaptation of the principle involved in the Maignen apparatus (1884) for softening water by the use of a dry powder "Anti-calcaire."

Mr. Allen Hazen in *Engineering Record*, July 19, 1913, describes and illustrates a device for applying aluminum sulphate: A screw-conveyor is operated in the bottom of a hopper by a motor (electric or water). Variations in the speed of the screw are controlled, first, by a system of multiple gearing admitting of easy and wide change and second, by changing the speed of the motor. This apparatus designed in 1907 by Mr. Hazen for Brisbane, Australia, was worked out in its mechanical details by Mr. R. S. Weston, who installed a copy at Knoxville, Tennessee. Mr. Hazen states

that similar apparatus has been installed in a number of other plants with which he has had to do, and mentions the practical working of the device with aluminum sulphate and experimental success with calcium hypochlorite by the introduction of an "arrangement similar in construction to a meat chopper in the bottom of the hopper, above the screw, and operating it by the same motive power as the screw," to break up lumps and reduce the material to a size that can be handled by the screw.

In 1910 Mr. W. Donaldson devised an apparatus in which friction drive of a worm gear actuates the screw, permitting a nice adjustment of the weight of substance delivered through a wide range. Nine of these devices are in use in seven plants; eight, for applying hydrated lime, and one for sulphate of iron. Attempts to use it for soda ash have been unsatisfactory. Mr. Donaldson has made no publication concerning the apparatus, which seems worthy of a detailed description.

The matter of dry feed has been in the minds of many water works men for a number of years. What has been the genetic relation between the various developments mentioned, the writer will not undertake to say. It is probably true that the question has been in the air for a long period, and has received a wider consideration than any one has realized.

Perhaps some standardization of these devices may come about, such as has occurred in other apparatus for water treatment, filter control and the like, so that each user may not find it necessary to design throughout an apparatus for his particular need. In very large plants automatic scales are practical, as experience at St. Louis has demonstrated. For plants of medium and small size, dry feeding has proved feasible in a number of cases.

Regarding the measure of success which may be hoped for in any instance, the physical character of the material plays an important part. Mr. Hazen calls attention to the necessity of having sulphate of aluminum crushed to a smaller size than that ordinarily used, that it may be fed dry, and to the difficulty with calcium hypochlorite on account of its physical properties. It may be of interest to call attention to those specific properties of substances in common use, which affect their adaptability to this method of application.

The properties of a substance which affect its storage are closely related to the success of feeding devices. A model substance for

application in this way should be uniform in size, constant in composition, permanent under prevailing conditions of temperature and pressure, and neither hygroscopic nor efflorescent.

Perhaps the most remote from this is calcium hypochlorite; because of its instability, its disagreeable odor, and its tendency to take up moisture, all of which connote loss of efficiency, as well as the mechanical difficulty of feeding regularly a more or less moist and lumpy material, dry feed for hypo seems impracticable.

Aluminum sulphate if fairly fine and uniform gives no trouble. It is stable at prevailing temperatures, not hygroscopic, does not cake, or bridge readily. Especially advantageous is dry feeding, as reducing to a minimum the corrosive action of a solution on pipes which convey it.

Hydrated lime of good quality for water treatment is now a commercial product, costing more of course than its equivalent of lump lime. But in many instances this excess would be almost or wholly met by the general simplification of the plant and the lowered cost of attendance.

As now manufactured it is air-separated and so uniform in size that 99.68 per cent will pass a 100-mesh, and 97.98 per cent a 200-mesh sieve. That it has a tendency to bridge over an orifice is a difficulty which has to be met where automatic scales are used in filling it into bags at the place of manufacture, as well as in the dry feed apparatus. The same trouble occurs with any fine amorphous material. Deterioration is proportional to the pressure of carbon dioxide to which it is exposed. This is ordinarily very small, save for purely local conditions. Because of its great uniformity it is especially well adapted to dry feed.

Lump lime is applied with automatic scales at St. Louis and at Columbus. The difficulty of adapting the scales to closely control coarse and fine material has not been wholly overcome. It is impossible to crush this material without fines, and wasteful to eliminate them. But the fines bridge as badly as hydrated lime, with resultant overloading and overdosing. Still a great improvement has been made within the past six years, and the method may be accounted successful. The storage problem in handling large quantities of lime is associated with the mechanical rather than with the chemical side, in that the upkeep of conveying machinery is the serious feature rather than deterioration in quality. If kept in bins that are practically air tight no deterioration occurs. It has

long been known that carbonation occurs at ordinary temperature only after hydration. If, therefore, access of moist air into this material is prevented, carbonation prior to slaking will be nil. Dry feeding to slaking tanks discharging directly into the water to be treated has the advantage of space economy and of freedom from incrustation in pipe systems with troublesome stoppages.

With iron sulphate a difficulty arises in the physical behavior of the substance under temperature conditions occurring at some time during almost every day from June to late September. The ordinary pure sulphate contains seven molecules of water of crystallization. In behavior it is similar to copper sulphate, which furnishes the stock illustration of the Phase Rule to crystals of hydrated salts. It has been shown by Hofman and Wanjukow that at 21°C. (70° Fahr.) in a stream of air this crystal form loses three molecules of water and passes over into pale green crystals having but four molecules of water ($FeSO_4.4H_2O$) which at 80°C. (176° Fahr.) lose three molecules, undergo a transformation at 132°C. and begin to be oxidized very slowly at 167°C.; oxidation continues with the rise to 455°C. when conversion to $Fe_2O_32SO_3$ is complete, and the last molecule of water is expelled.

This first transition to $FeSO_4.4H_2O$ occurs to a limited extent in summer shipment in bags or in bulk, so that the material has a green gray appearance commonly. The extent to which alteration occurs does not greatly change the composition, only making analyses show a trifle more than 100 per cent of ferrous sulphate, ($FeSO_4.7H_2O$). But the slight efflorescence of exposed layer serves to inoculate the whole mass with the lower hydrate, facilitating the transformation.

If such a mass is stored in a closed bottle or other container at a temperature of 21°C. or slightly higher the resulting loss of water of crystallization in one part gives rise to a new trouble. The water vapor given off in the warmer layer is lighter than air; condensing on cooler particles, it is taken up by some pale green particles of the lower hydrate and in their re-crystallization in contact with other dark green ordinary crystals there is a cementing into masses of considerable size.

When iron sulphate is stored in large bins which are dust proof and almost air tight, a similar condition occurs. At St. Louis the bins are 20 feet in diameter and 40 feet deep. There have been times within the past six years when the whole content of a bin

was in one mass. Again the bottom portion might be less firm than the upper, so that a cylindrical portion was supported over an air filled space below; or an opening about two feet in diameter remained surrounded by a cylinder whose walls were nine feet thick. Even in a smaller bin which was refilled at frequent intervals this caking occurred to such an extent that its effective holding capacity was limited to a nearly cylindrical vertical opening through the central portion. However, this caked material lost nothing but a modicum of water, and had suffered a concentration rather than a deterioration, since it has been shown that oxidation occurs only at high temperatures.

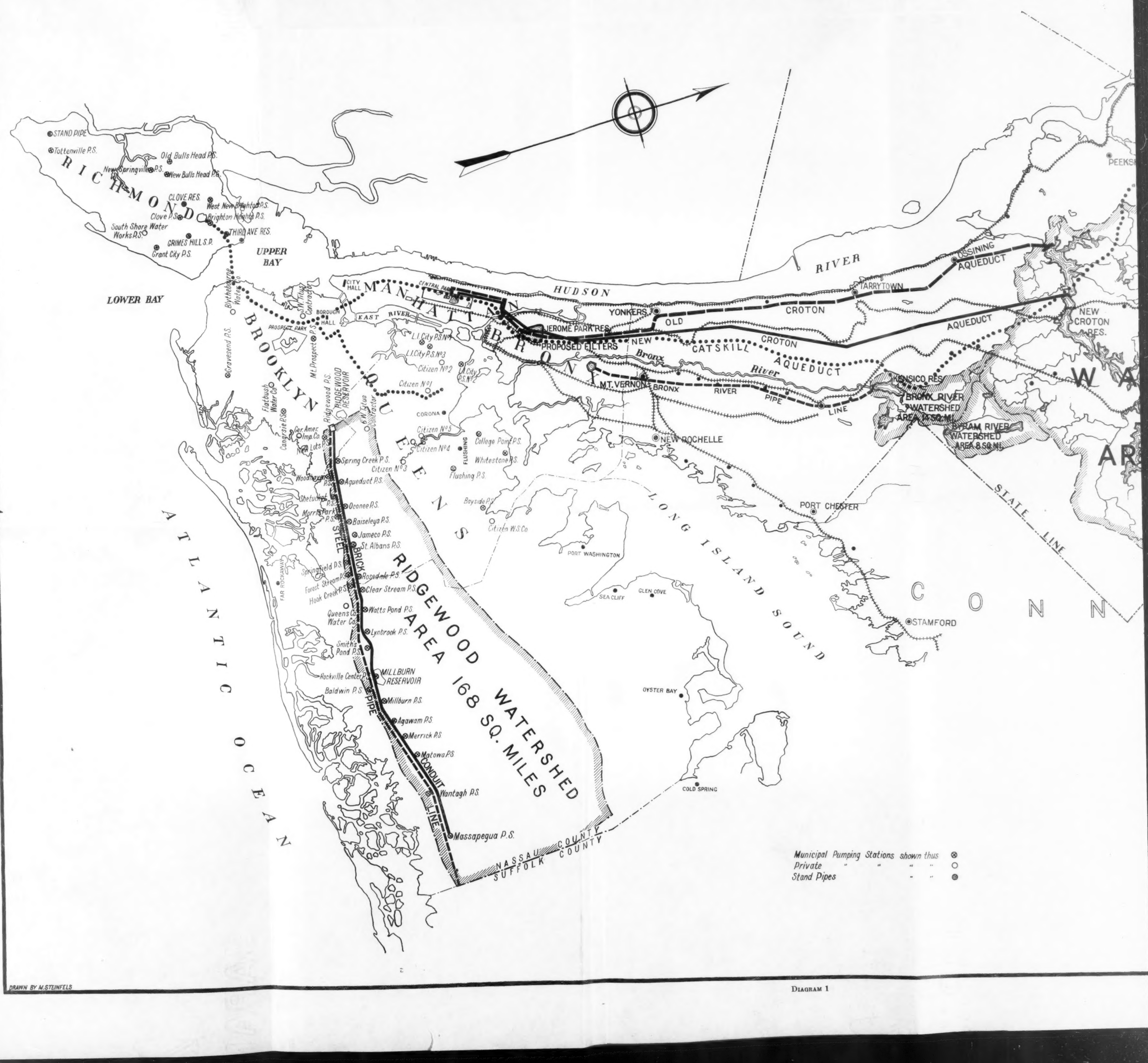
With a well designed crusher it can be prepared for dry feeding. It is necessary that a fair degree of uniformity be given this as any other material which is to be fed through an orifice. In July to September of 1913 when caked material was imperfectly crushed and fed, analyses of the solution checked against the volume of water (metered) gave results ranging as low as 45 per cent. The results were obtained with an orifice, where material and voids are measured together, and with material that was coarse, with more or less abundant lumps of all sizes.

It is therefore important in using dry feed for iron sulphate, that the material be fairly uniform or freshly crushed and fed from a small open hopper frequently filled. Under these conditions, which will be readily met in a plant of medium size, iron sulphate may be successfully fed, for the difficulties mentioned arise from storage in large bulk. In bags which permit the escape of liberated water vapor, serious caking from this cause has not been observed. It is probable that shallow bins open to the air would be less subject to troublesome caking than the deep and relatively narrow ones here referred to. Whether a dry feed machine or automatic scales are used should be determined by the size of the plant. For large plants undoubtedly the scales are best adapted as being less sensitive to size variation than an orifice device or a screw conveyor.

Whatever method of feeding iron sulphate be adopted consideration should be given to the possibility of growth of algae in the solution. So far as the writer is aware this has not been discussed, although doubtless others have noted such growth in moderately strong solutions of this neutral salt, as well as the common development in iron bearing waters carrying but a few parts per million of iron. In a solution of one and one-half pounds sulphate of iron

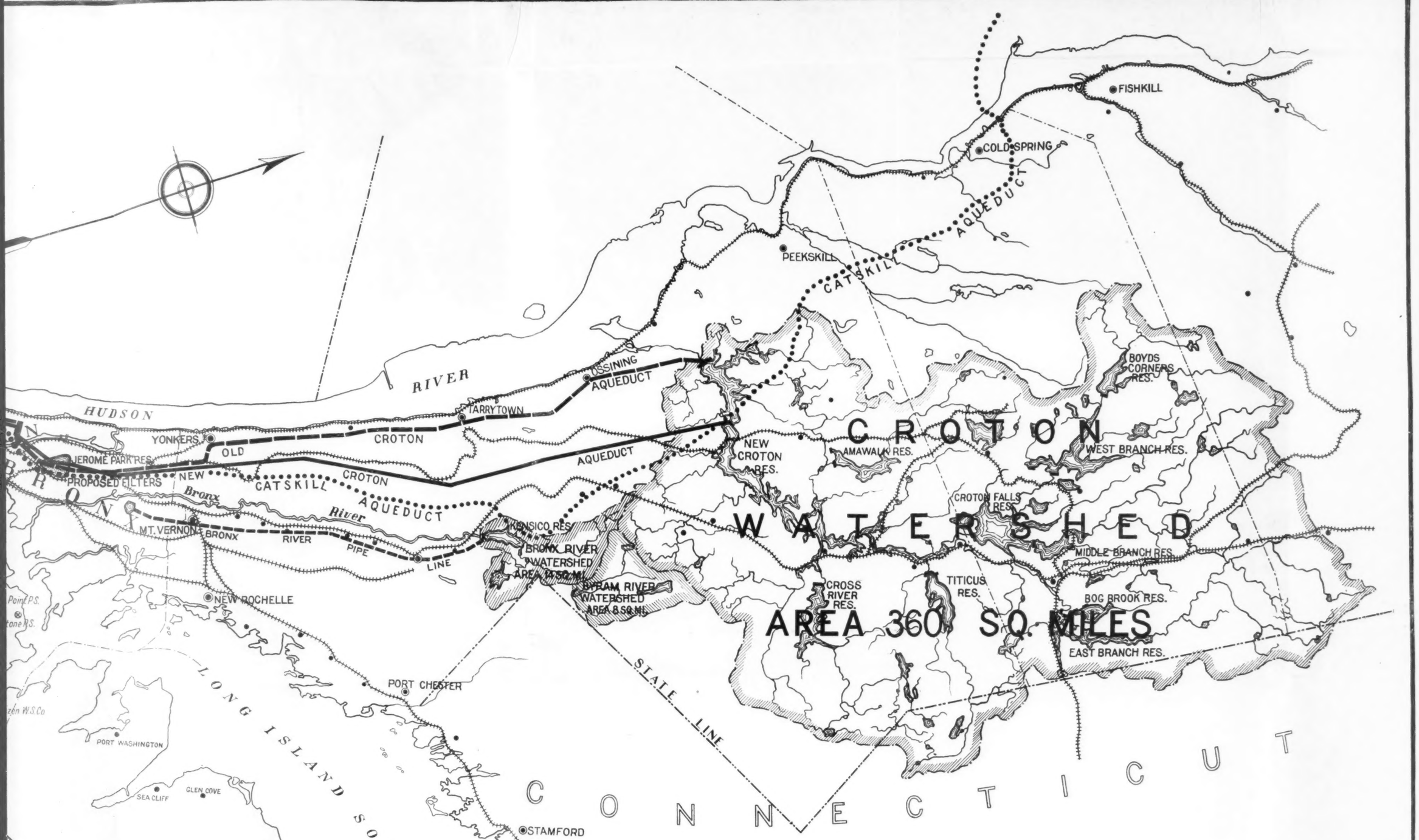
per gallon, equivalent to more than 3700 parts of iron (Fe) per million, the growth at and near the surface was heavy and of such consistency that lumps of it breaking loose from the tank walls were firm enough to clog the outlet. It is inexpedient to use long pipe systems in conveying a solution in which such a growth may develop.

It is apparent that each substance presents the virtues and defects of its properties. It is essential that these be recognized and considered in adopting a method of feeding. Dry feed for alum, lime and iron sulphate offers certain advantages in permitting a reduction in the extent of pipes and the number of valves and fittings exposed to corrosion, incrustation, or stoppage from growths; economy of space in plant arrangement; a possible economy of attendance, and ready control of applied chemicals.



DRAWN BY M. STEINFELS

DIAGRAM 1



CITY OF NEW YORK

DEPT. OF WATER SUPPLY, GAS & ELECTRICITY

BUREAU OF WATER SUPPLY

SOURCES OF WATER SUPPLY

FOR

MUNICIPAL AND PRIVATE SYSTEMS

MAY 1912

Scale of Miles 0 1 2 3 4 5

Chief Engineer

DIAGRAM 1

MAINTENANCE OF THE WATER SUPPLY DISTRIBUTION SYSTEM OF NEW YORK CITY

PRESENTED AT MEETING OF NEW YORK SECTION OF THE AMERICAN WATER WORKS ASSOCIATION, THURSDAY, DECEMBER 3, 1914.

BY WILLIAM W. BRUSH

Engineers are prone to give first place to the construction of new works and consider that the maintenance of engineering works does not present problems of equal importance or interest. Such an attitude is unfortunate, and is generally based on a lack of knowledge of the magnitude of maintenance problems and the opportunities in maintenance work for the display of engineering and organizing ability of the highest order.

One of the results of the engineer's failure to appreciate the proper position of maintenance work in the engineering field is the relatively few papers published on this subject. The difficulty of obtaining data on organization and methods in use in large maintenance operations is strong testimony to the truth of the above statement. The writer has, therefore, prepared the following description of the maintenance of the distribution system of New York City, believing that more published information on such subjects would be helpful to the profession.

The distribution system of New York covers an area which is 35 miles long and 20 miles broad, and divided by canals, rivers and bays which have to be crossed by the distribution mains. A number of islands having a population varying from a few hundred to several thousand must also be supplied, and add to the complexity of the problem. See Diagram No. 1.

Eight distribution reservoirs of a total capacity of 2500 m.g., with surfaces varying from 119 feet to 250 feet above tide level, and eight stand pipes, with overflows varying from 140 feet to 453 feet above tide level, are used to equalize the flow to the fourteen separate services in the five boroughs. See Table No. 1. Excluding tunnels and masonry conduits, there are 2800 miles of mains of sizes

varying from 4 inches in diameter up to 60 inches in diameter, to which are connected 60,000 valves, 43,000 hydrants and over 360,000 services. The details are given in Table No. 2. Over 500 m.g.d. are delivered through this system.

The services for each borough are shown on the accompanying diagram, No. 2, which indicates both the area supplied and the

TABLE 1

Watersheds—areas, capacities, drafts, etc.

WATERSHEDS	AREA OF WATERSHED SQ. MI.	SAFE YIELD M.G.	POINT OF DISTRIBUTION	CAPACITY MILLION GALLONS	*ELEV. OF POINT OF DIST.	PRESENT DRAFT FROM WATERSHED M.G.D.
Croton.....	360	336	Jerome Av. Tower	0.039	303	
			Jerome Park Res.	773.000	134	
			High Bridge Tower	0.045	336	329
			High Bridge Res.	11.000	218	
			Central Park Res.	1200.000	119	
Bronx and Byram.....	22	15	Williamsbridge Res.	140.000	197	18
Brooklyn.....	New 97	150	Ridgewood Res.	304.000	172	
	Old 71		Mt. Prospect Res.	19.185	200	134
			Mt. Prospect Tower	0.112	280	
Queens, 3rd Ward.....	Driven well system.	6	College Pt. Standpipe	0.895	192	
	Makes watershed limits indefinite.		Flushing Standpipe	0.800	221	15
			Ridgewood Res.†	304.000	172	
Richmond....		9	Tottenville Standpipe	0.140	143	
			Grymes Hill Standpipe	0.220	453	
			Third Ave. Res.	0.800	212	12
			Clove Res.	2.900	254	

* Datum = Mean sea level at Sandy Hook.

† Brooklyn system furnishes about 10 m.g.d. to 1st Ward.

elevation of reservoir or stand pipe controlling the hydraulic gradient. In addition to the domestic system, there are three separate high pressure fire systems covering over 7200 acres with 170 miles of mains from 8 inches to 24 inches in diameter, on which are located 4100 hydrants and 6650 valves.

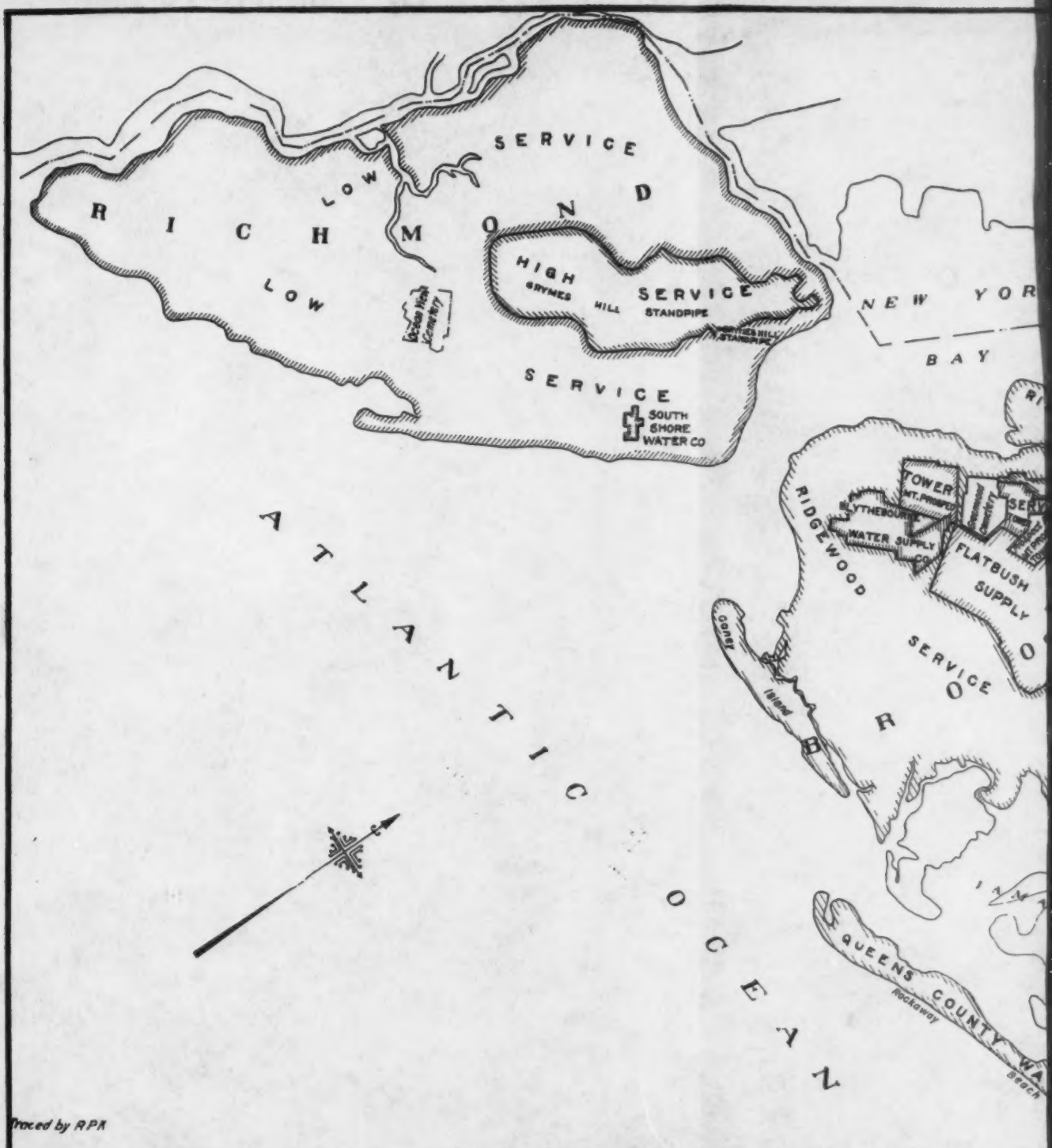
To the existing system there is to be added in about a year the great Catskill system, with its 17 miles of rock tunnel, 22 feeding

TABLE 2

Distribution mains, valves and hydrants in place—1914

	MANHATTAN AND BRONX	BROOKLYN	QUEENS	RICHMOND
inches	*feet*	*feet*	*feet*	*feet*
Mains				
60	800	.....	.....	.....
48	245,000	166,000	.....	.....
36	281,000	61,000	.....	.....
30	54,000	89,000	46,000	16
24	13,000	42,000	42,000	53,000
20	529,000	371,000	38,000	59,000
16	34,000	266,000	35,000	50,000
14	2,000	3,000	7,000	11,000
12	245,000	562,000	250,000	263,000
10	14,000	20,000	32,000	29,000
8	148,000	69,000	440,000	270,000
6	3,345,000	2,122,000	303,000	302,000
4	133,000	137,000	42,000	307,000
Total	5,043,800	3,908,000	1,235,000	1,344,016
Valves				
48	65	24	.....	.....
36	111	69	.....	.....
30	45	82	9	.....
24	21	77	11	.....
20	555	702	62	80
16	31	656	28	50
14		1	9	21
12	6,763	1,629	703	304
10	10	7	45	41
8	551	4,813	1,233	917
6	19,936	14,044	2,020	2,262
4	375	134	34	1,031
Total	28,463	22,238	4,154	4,706
Hydrants				
Total (all patterns)	20,125	17,782	2,798	2,593

shafts, and 16 miles of delivery mains, varying on land from 48 inches to 66 inches in diameter, and including two miles of 36 inch submerged pipe, connecting Brooklyn with Richmond.



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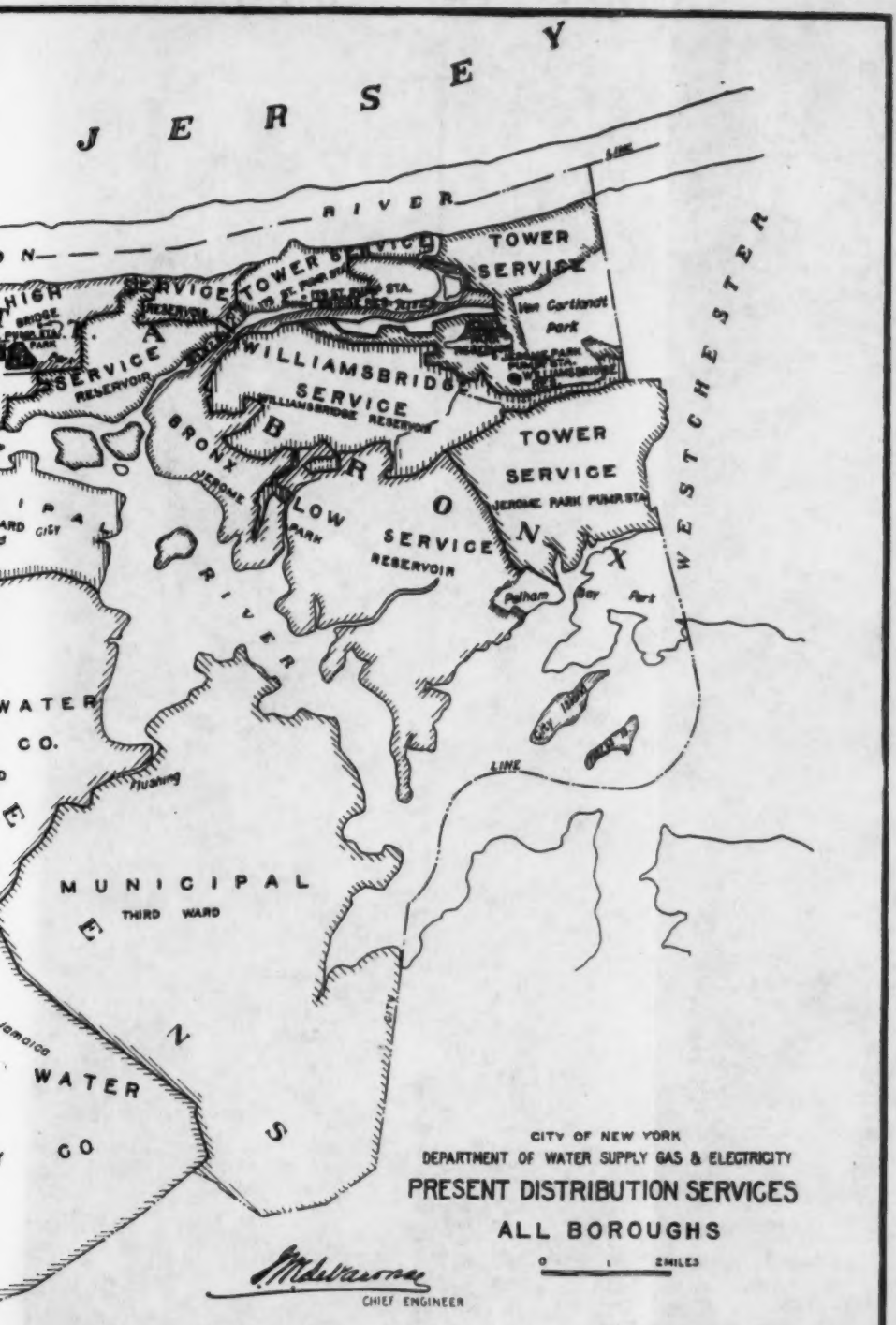
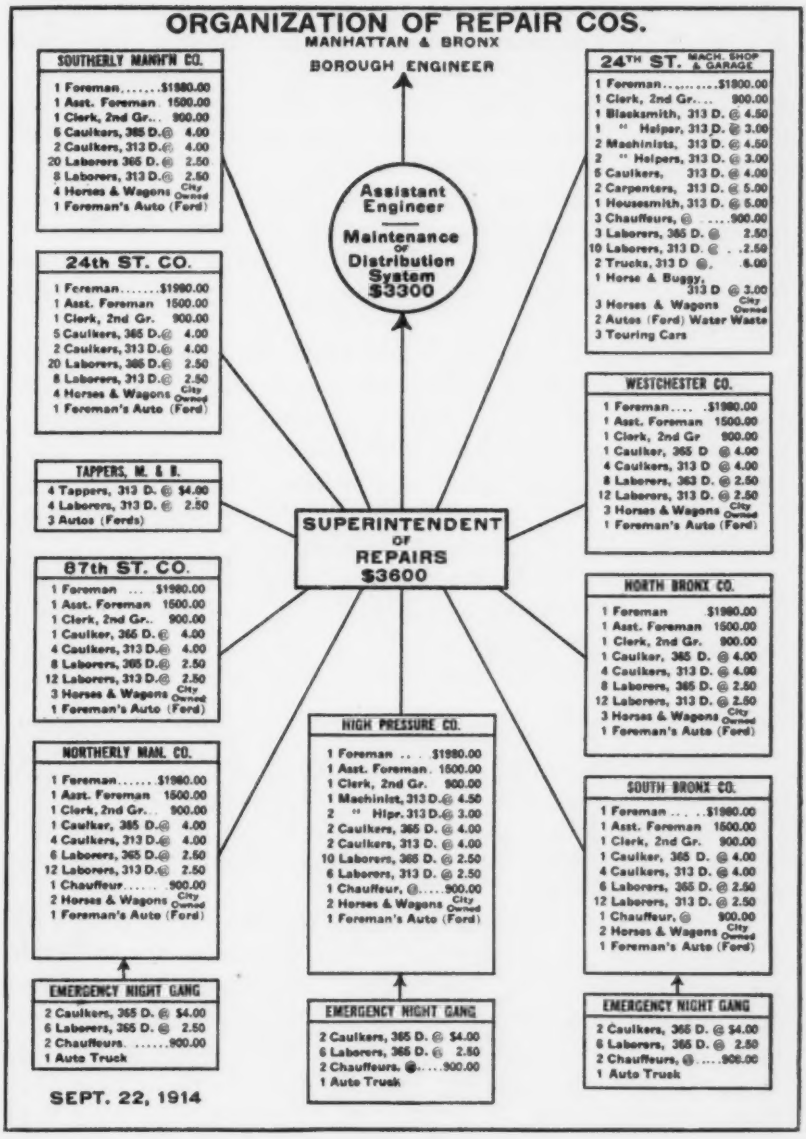
NEW
HUDSON
NEW YORK
STATE
BAY
MANHATTAN
CENTRAL
PARK
EAST
RIDGEWOOD
MAIN HIGH SERVICE
TOWER
MAIN
SERVICE
RESERVOIR
WATER SUPPLY CO.
FLATBUSH
SUPPLY WATER CO.
HIGH SERVICE
CITIZENS WATER
SUPPLY CO.
SECOND WARD
GERMAN-AMERICAN
IMPROVEMENT CO.
WOODHAVEN
WATER SUPPLY
CO.
JAMAICA WATE
SUPPLY CO
QUEENS COUNTY WATER CO.
Rockaway
Beach
Coney
Island
JAMAICA
BAY
OCEAN

DIAGRAM 2


JERSEY
RIVER
TOWER SERVICE
New Cortlandt Park
WILLIAMSBRIDGE SERVICE RESERVOIR
WILLIAMSBRIDGE SERVICE
BRONX
JEROME PARK PUMP STA.
TOWER SERVICE
JEROME PARK PUMP STA.
LOW SERVICE RESERVOIR
PARK
RIVER
Pelham Bay Park
WESTCHESTER
LINE
MUNICIPAL
THIRD WARD
WATER CO.
WATER CO
CITY OF NEW YORK
DEPARTMENT OF WATER SUPPLY GAS & ELECTRICITY
PRESENT DISTRIBUTION SERVICES
ALL BOROUGHS
0 1 2 MILES
CHIEF ENGINEER

M.S. 26 FILE C


ORGANIZATION OF REPAIR COS.
MANHATTAN & BRONX
BOROUGH ENGINEER
Assistant Engineer
Maintenance of Distribution System
$3300
SUPERINTENDENT OF REPAIRS
$3600
SOUTHERLY MANH'N CO.
1 Foreman.....$1980.00
1 Asst. Foreman 1500.00
1 Clerk, 2nd Gr... 900.00
6 Caulkers, 365 D.@ 4.00
2 Caulkers, 313 D.@ 4.00
20 Laborers 365 D. @ 2.50
8 Laborers, 313 D.@ 2.50
4 Horses & Wagons City Owned
1 Foreman's Auto (Ford)
24th ST. CO.
1 Foreman.....$1980.00
1 Asst. Foreman 1500.00
1 Clerk, 2nd Gr. 900.00
5 Caulkers, 365 D.@ 4.00
2 Caulkers, 313 D.@ 4.00
20 Laborers, 365 D.@ 2.50
8 Laborers, 313 D.@ 2.50
4 Horses & Wagons City Owned
1 Foreman's Auto (Ford)
TAPPERS, M. & B.
4 Tappers, 313 D. @ $4.00
4 Laborers, 313 D. @ 2.50
3 Autos (Fords)
87th ST. CO.
1 Foreman ... $1980.00
1 Asst. Foreman 1500.00
1 Clerk, 2nd Gr.. 900.00
1 Caulker, 365 D. @ 4.00
4 Caulkers, 313 D.@ 4.00
8 Laborers, 365 D.@ 2.50
12 Laborers, 313 D.@ 2.50
3 Horses & Wagons City Owned
1 Foreman's Auto (Ford)
NORTHERLY MAN. CO.
1 Foreman.....$1980.00
1 Asst. Foreman 1500.00
1 Clerk, 2nd Gr.. 900.00
1 Caulker, 365 D.@ 4.00
4 Caulkers, 313 D.@ 4.00
6 Laborers, 365 D.@ 2.50
12 Laborers, 313 D.@ 2.50
1 Chauffeur..... 900.00
2 Horses & Wagons City Owned
1 Foreman's Auto (Ford)
EMERGENCY NIGHT GANG
2 Caulkers, 365 D. @ $4.00
6 Laborers, 365 D. @ 2.50
2 Chauffeurs. 900.00
1 Auto Truck
SEPT. 22, 1914
24TH ST. MACH. SHOP & GARAGE
1 Foreman.....$1900.00
1 Clerk, 2nd Gr.... 900.00
1 Blacksmith, 313 D. @ 4.50
1 " Helper, 313 D. @ 3.00
2 Machinists, 313 D. @ 4.50
2 " Helpers, 313 D. @ 3.00
5 Caulkers, 313 D. @ 4.00
2 Carpenters, 313 D. @ 5.00
1 Housesmith, 313 D. @ 5.00
3 Chauffeurs, @ 900.00
3 Laborers, 365 D. @ 2.50
10 Laborers, 313 D. @ .2.50
2 Trucks, 313 D @. 6.00
1 Horse & Buggy, 313 D @ 3.00
3 Horses & Wagons City Owned
2 Autos (Ford) Water Waste
3 Touring Cars
WESTCHESTER CO.
1 Foreman..... .$1980.00
1 Asst. Foreman 1500.00
1 Clerk, 2nd Gr 900.00
1 Caulker, 365 D @ 4.00
4 Caulkers, 313 D @ 4.00
8 Laborers, 363 D. @ 2.50
12 Laborers, 313 D. @ 2.50
3 Horses & Wagons City Owned
1 Foreman's Auto (Ford)
NORTH BRONX CO.
1 Foreman $1980.00
1 Asst. Foreman 1500.00
1 Clerk, 2nd Gr. 900.00
1 Caulker, 365 D. @ 4.00
4 Caulkers, 313 D. @ 4.00
8 Laborers, 365 D. @ 2.50
12 Laborers, 313 D. @ 2.50
3 Horses & Wagons City Owned
1 Foreman's Auto (Ford)
SOUTH BRONX CO.
1 Foreman $1980.00
1 Asst. Foreman 1500.00
1 Clerk, 2nd Gr. 900.00
1 Caulker, 365 D. @ 4.00
4 Caulkers, 313 D. @ 4.00
6 Laborers, 365 D. @ 2.50
12 Laborers, 313 D. @ 2.50
1 Chauffeur, @ 900.00
2 Horses & Wagons City Owned
1 Foreman's Auto (Ford)
EMERGENCY NIGHT GANG
2 Caulkers, 365 D. @ $4.00
6 Laborers, 365 D. @ 2.50
2 Chauffeurs, @ 900.00
1 Auto Truck
HIGH PRESSURE CO.
1 Foreman ... $1980.00
1 Asst. Foreman 1500.00
1 Clerk, 2nd Gr. 900.00
1 Machinist, 313 D.@ 4.50
2 " Hlpr. 313 D.@ 3.00
2 Caulkers, 365 D. @ 4.00
2 Caulkers, 313 D. @ 4.00
10 Laborers, 365 D. @ 2.50
6 Laborers, 313 D. @ 2.50
1 Chauffeur, @.....900.00
2 Horses & Wagons City Owned
1 Foreman's Auto (Ford)
EMERGENCY NIGHT GANG
2 Caulkers, 365 D. @ $4.00
6 Laborers, 365 D. @ 2.50
2 Chauffeurs. @.....900.00
1 Auto Truck

The maintenance of this system involves an organization and equipment of sufficient size and capacity to promptly respond and shut off the flow of water in case of accident, to promptly repair a broken main, of whatever size it may be, to repair or replace defective hydrants and valves, to cut in new hydrants and valves, to make new connections, to tap the mains for new services, to test service boundaries, to measure flow in trunk and lateral mains, to locate mains and services, to locate and repair leaks on mains, to test meters, to record pressures in system, to control pressures by operation of head gates at reservoirs, to respond to fire alarms, to investigate causes of lack of pressure, to locate and stop leaks and waste in premises, etc.

The organization to handle this work is controlled by the chief engineer, and is directed by four borough engineers, one for each borough, except The Bronx, which is consolidated with Manhattan, the sources of supply being mainly the same for these two boroughs. Under each borough engineer there is an assistant engineer in charge of distribution, with his assistants, foremen, assistant foremen, caulkers, laborers, etc., as shown on Diagram No. 3.

In Manhattan and The Bronx a superintendent is in direct charge of all the repair companies, while in Brooklyn a general foreman has charge of these companies.

The meter shops and the machine shops have their separate forces.

In Brooklyn an assistant engineer with one field party handles all measurements of flow in mains, while for the other boroughs, an assistant engineer with two field parties is assigned to this work. Separate labor gangs operate gates, place taps for measurement of flow, locate leaks, etc., under the direct control of the measurement of flow parties.

To promptly and economically handle the field maintenance work connected with the distribution system it is necessary to divide the territory covered by said system. As borough lines are generally recognized as lines of division for New York City activities, these have been used as the boundaries of the major divisions of territory. Each borough has been divided into districts, with a repair company under the direction of a foreman assigned to such district. Separate provision has been made for the high pressure fire service system. The repair companies in the various boroughs are as follows:

Manhattan. Four low pressure companies and one high pressure repair company.

Brooklyn. Four companies, the high pressure system being handled by an assistant foreman and gang under the foreman of a repair company.

Bronx. Three companies.

Queens. Two companies.

Richmond. Three companies.

The force and rates of pay for employes have already been given for each company. Table No. 3 gives the number of men, annual payroll, area covered, miles of mains and number of valves and hydrants for each company. The more important items of work done by these repair companies are given for each borough.

REPAIR COMPANY ORGANIZATION

The gang organization has a caulker as the head, with from three to six laborers as assistants, depending upon the nature of the work. To each such gang is assigned a horse and wagon that transport the gang to and from the work, and deliver material and tools required. Where a larger force is required, two or more gangs are consolidated, working under the direction of one of the caulkers or an assistant foreman.

The foreman has general supervision over all the gangs and is expected to spend a large percentage of his time in the field. The assistant foreman takes charge in the field of major repairs, and supplements the foreman's supervision of field work. A clerk assigned to each company, except the small companies in Queens and Richmond, records time, material and labor expended on each job, complaints received and action thereon, etc.

Repair Company Headquarters

In general, the buildings used for repair company headquarters are inadequate; only one modern building, that on East 24th Street, being now in use. Efforts are being made to remedy this condition. One new building in Manhattan and two in Brooklyn are nearing completion and plans have been prepared and money authorized for three additional buildings for headquarters in Brooklyn, Queens and Richmond, respectively.

TABLE 3

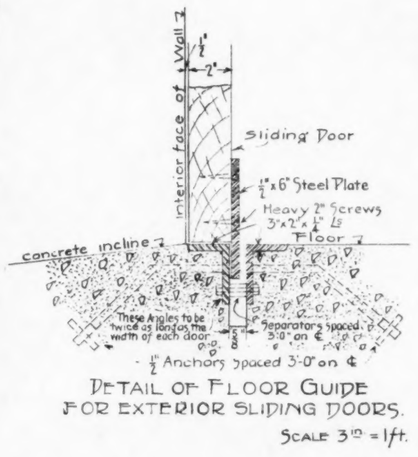
Repair companies—Area covered and cost of payroll per hydrant and per mile of main

REPAIR CO.	NO. MEN		PAYROLL	AREA COVERED (SQ. MILE)	MILES OF MAINS =12" MAIN	NO. HYDRANTS	NO. VALVES	COST PER MILE	COST PER HYDRANT
	Skilled	Unskilled							
Manhattan and Bronx									
Worth Street	7	36	50,675	3.3	113.5	2744	3201	$446	$18
35th Street	5	28	35,355	2.1	107.5	1625	2085	329	22
24th Street	2	30	37,259	2.1	97.7	1916	2440	381	19
87th Street	3	26	32,954	7.4	254.2	2945	3304	130	11
Harlem	3	30	37,155	5.0	365.2	2791	3137	102	13
Ft. George	1	13	16,367	2.1	48.9	831	1212	335	20
South Bronx	2	35	40,732	8.8	167.7	3567	4290	243	11
North Bronx	2	27	31,951	9.3	175.7	1847	2532	182	17
Westchester	3	17	22,978	22.1	93.0	1787	2079	247	13
High Pressure	2	23	27,999	5.8	126.1	2369	4062	222	12
Brooklyn									
Western District	9	73	78,726	13.5	353.0	5514	6866	223	14
Eastern District	4	47	48,260	6.54	158.0	2786	4637	305	17
East N. Y. Dist	5	44	48,822	10.56	173.0	2494	2509	282	20
Coney Island	3	36	45,975	24.1	219.0	6316	5789	210	7
High Pressure	1	10	10,825	4.8	51.0	1247	1727	212	9
Queens									
First Ward	2	23	22,318	8.0	80.0	1229	1224	278	18
Third Ward	1	18	17,401	34.0	90.0	1197	2203	192	15
Richmond									
West New Brighton	1	14	14,213	13.4	175.0	2332	4282	242	18
Clove	1	14	14,003	23.0					
Tottenville	1	10	10,398	21.0					

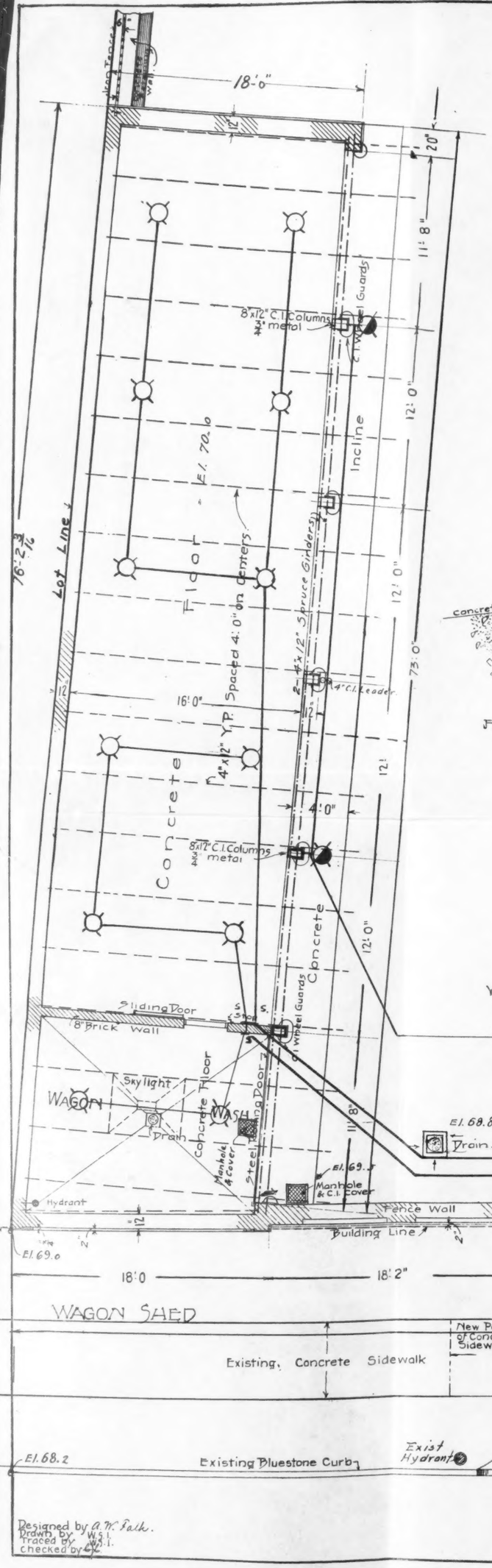
Tottenville	1	16	16,398	21.0)					

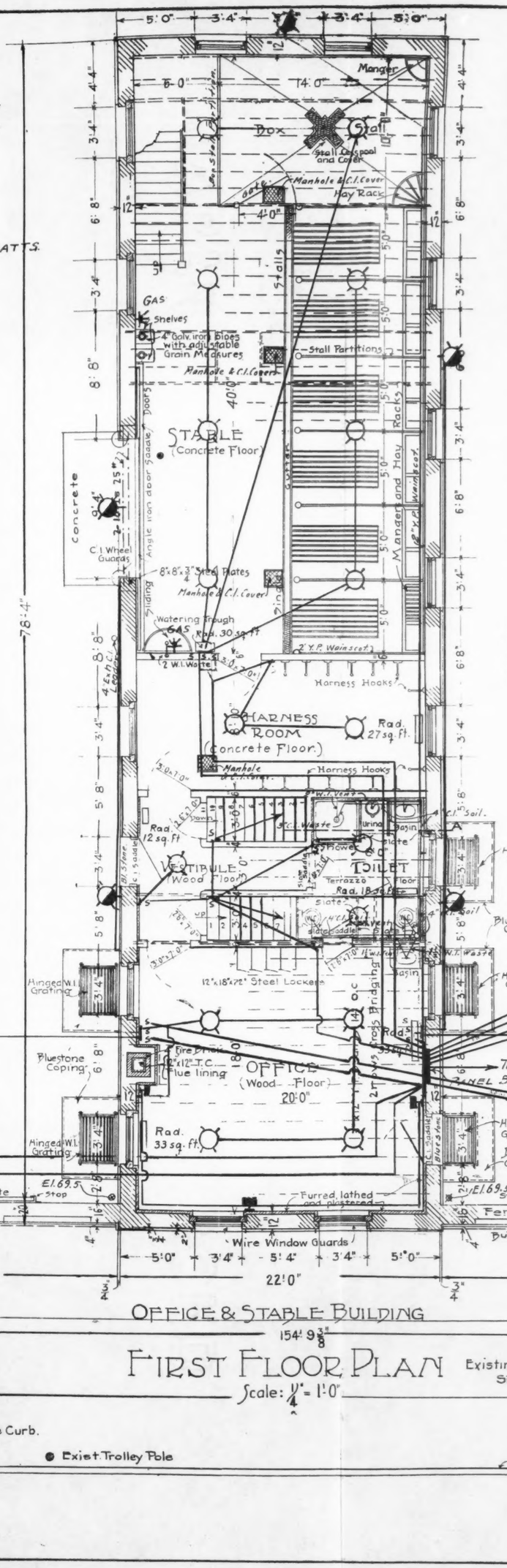
ELECTRIC LIGHTING SYMBOLS:

- CEILING FIXTURE, 100 WATTS.
- INSERTION PLUG RECEPTACLE, 100 WATTS.
- S. SWITCH
- WEATHER-PROOF FIXTURE AS SPECIFIED, 100 WATTS.

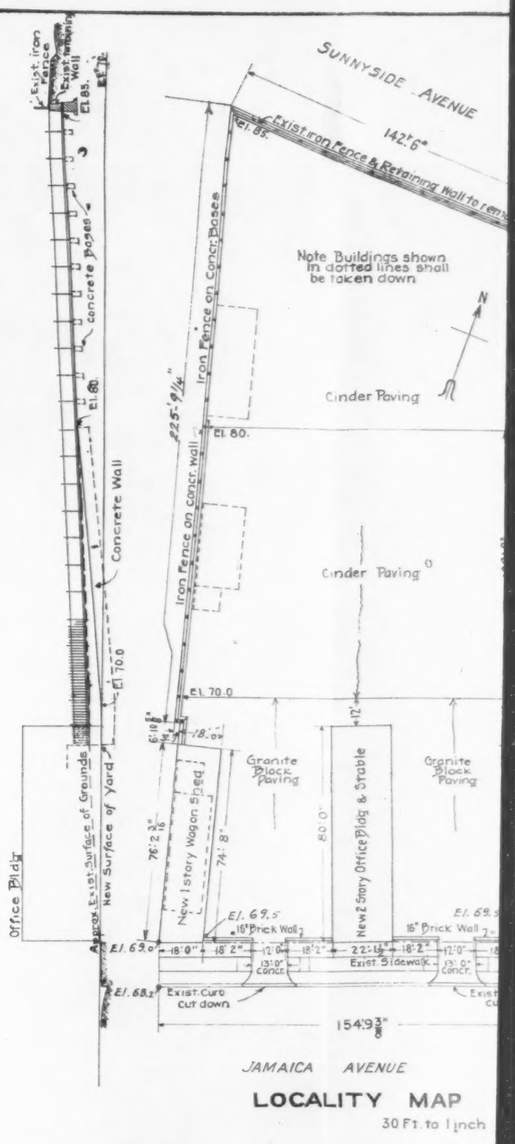

Sliding Door
Interior face of Wall
½"x6" Steel Plate
Heavy 2" Screws
3"x2"x¼" L's
Floor
Concrete Incline
These Angles to be twice as long as the width of each door
Separators spaced 3'-0" on ℄
½" Anchors spaced 3'-0" on ℄

DETAIL OF FLOOR GUIDE FOR EXTERIOR SLIDING DOORS.
SCALE 3" = 1ft.

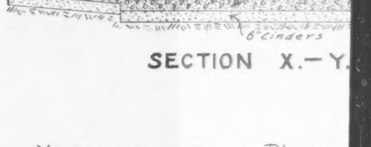




FIRST FLOOR PLAN
Scale: ¼" = 1'-0"



LOCALITY MAP
30 Ft. to 1 inch



SECTION X.—Y.

Designed by A. M. Falk.
Drawn by W.S.I.
Traced by W.S.I.
Checked by C.

TRIC LIGHTING SYMBOLS:

FIXTURE, 100 WATTS.

ON PLUG RECEPTACLE, 100 WATTS.

H

R-PROOF FIXTURE AS SPECIFIED, 100 WATTS.

Sliding Door

1/2"x6" Steel Plate

Heavy 2" Screws

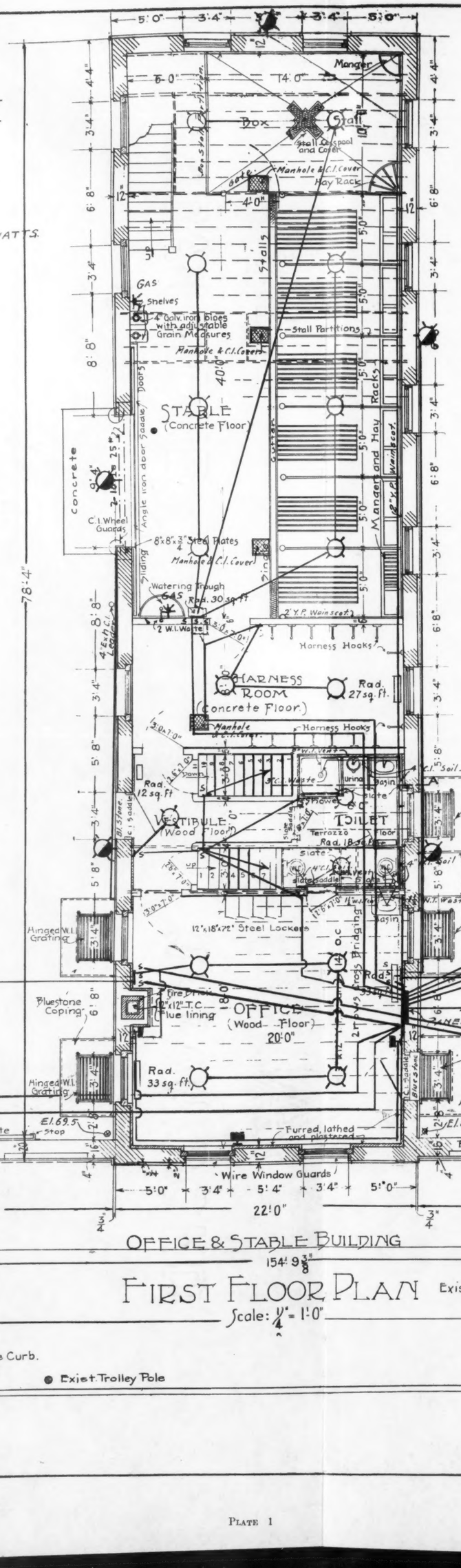
3"x2"x1/4" L

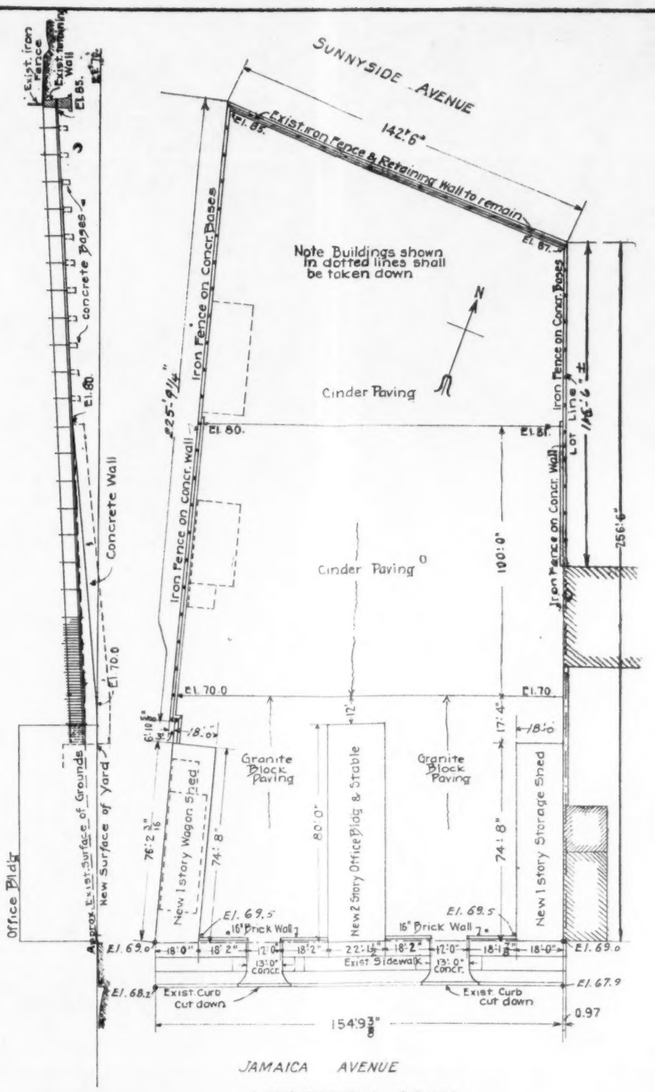
Floor

Separators spaced 3'0" on ℄

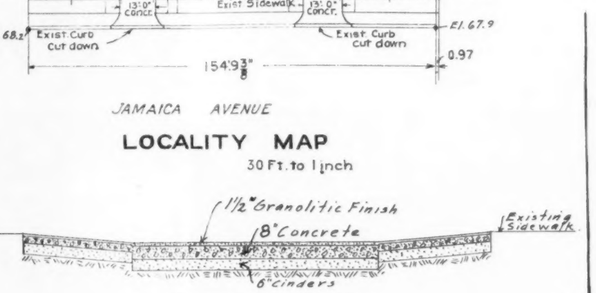
s spaced 3'0" on ℄

FLOOR GUIDE
R SLIDING DOORS.
SCALE 3" = 1ft.

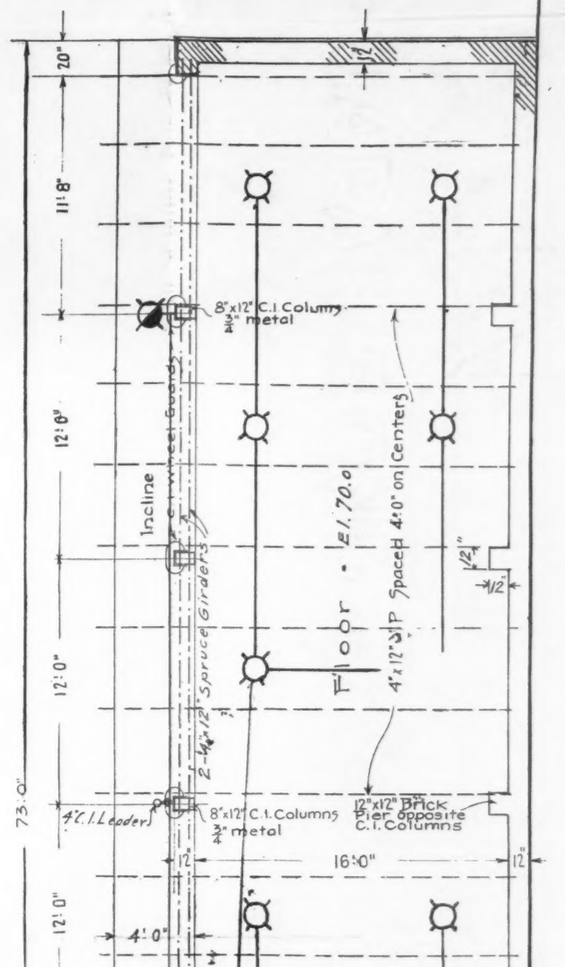


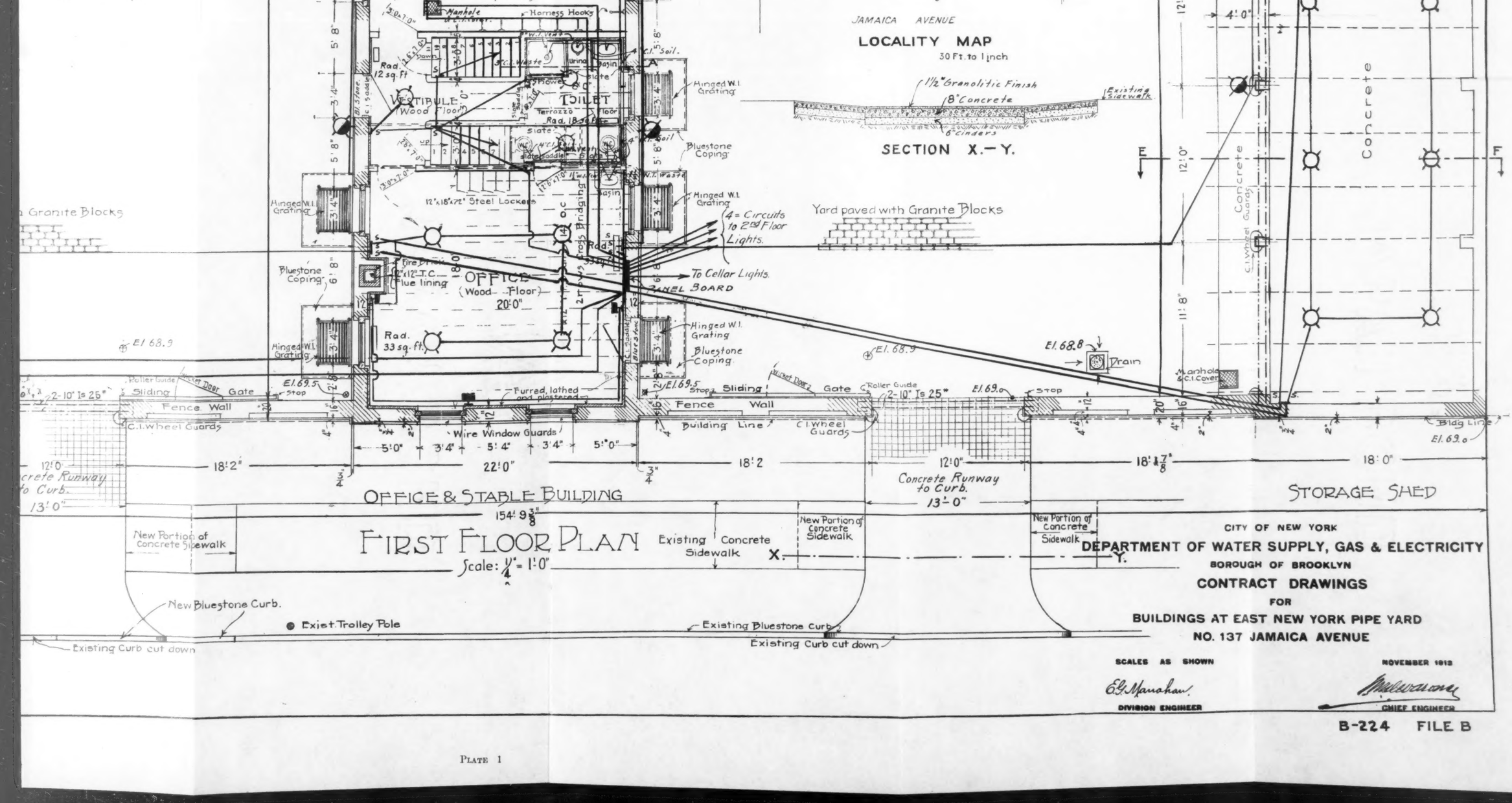


LOCALITY MAP
30 Ft. to 1 inch



SECTION X.—Y.





CITY OF NEW YORK
DEPARTMENT OF WATER SUPPLY, GAS & ELECTRICITY
BOROUGH OF BROOKLYN
CONTRACT DRAWINGS
FOR
BUILDINGS AT EAST NEW YORK PIPE YARD
NO. 137 JAMAICA AVENUE

SCALES AS SHOWN — NOVEMBER 1913

E.G. Manahan
DIVISION ENGINEER

CHIEF ENGINEER

B-224 FILE B

57

Plate No. 1 shows the ground and second floor plan of the East New York headquarters in Brooklyn, and Plates Nos. 2 and 3 are photographs of this building which is nearing completion.

Plate No. 4 is a photograph of the 24th Street Station, which serves as headquarters for a repair company, the meter testing shop, garage, blacksmith shop, machine shop and store yard.

Headquarters, such as that erected at East New York Station, cost about $25,000, exclusive of land, and can adequately provide for a force of forty men, six horses and six wagons, or automobiles. Space is provided under the sheds for the storage of valves and hydrants, it being expected that pipe and special castings would be stored in the open.

Equipment, Materials and Supplies

There is a natural tendency to hoard articles which may at some time be useful and which one may have had difficulty in obtaining in the past. Foremen in charge of repair companies have this very human trait, and the resulting accumulation of useful and useless material makes for confusion and inefficiency. As a corrective, a standard quota is set up for each repair company, the same quota being used where companies are of approximately equal size. This quota represents the equipment, materials and supplies, that should always be on hand, plus about one months' consumption of the materials and supplies. After such quota has been fixed, the surplus at each headquarters is removed and sent to a central storehouse, where it is placed in stock, or consigned to the scrap heap, if it is useless. At approximately the end of the month, the clerk makes a list of all equipment, materials and supplies consumed during the month and requisitions the storekeeper for such articles to replenish the depleted quota. If there is any unusual demand, the quota can be replenished at any time.

The tentative quota of equipment as shown in Table No. 4 may be useful for those who are setting up a similar standard.

Standardizing Materials, Pipe, Valves and Hydrants

All materials are purchased under definite specifications and are subjected to chemical and physical tests to determine compliance with standards. Samples are used as standards where it is difficult, if not impossible, to set up definite specifications.

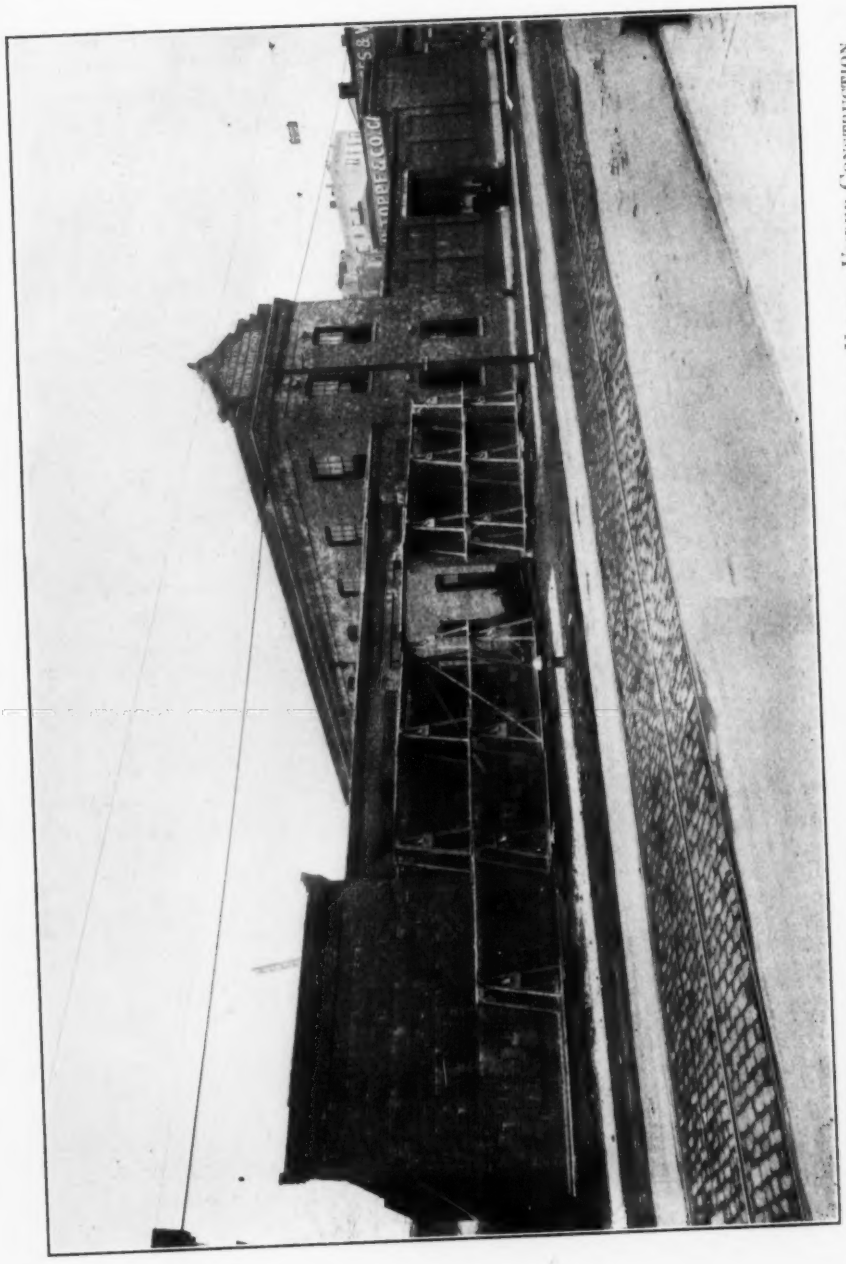


PLATE 2. EAST NEW YORK REPAIR YARD, BOROUGH OF BROOKLYN. EXTERIOR VIEW. UNDER CONSTRUCTION

PLATE 3. EAST NEW YORK REPAIR YARD, BOROUGH OF BROOKLYN, UNDER CONSTRUCTION. CENTRAL TWO STORY BUILDING TO BE USED FOR OFFICE, HEADQUARTERS FOR MEN, STOREROOM AND STABLE. ONE STORY SHEDS FOR STORAGE OF WAGONS, AUTOMOBILES, HYDRANTS, VALVES AND HEAVY MATERIAL

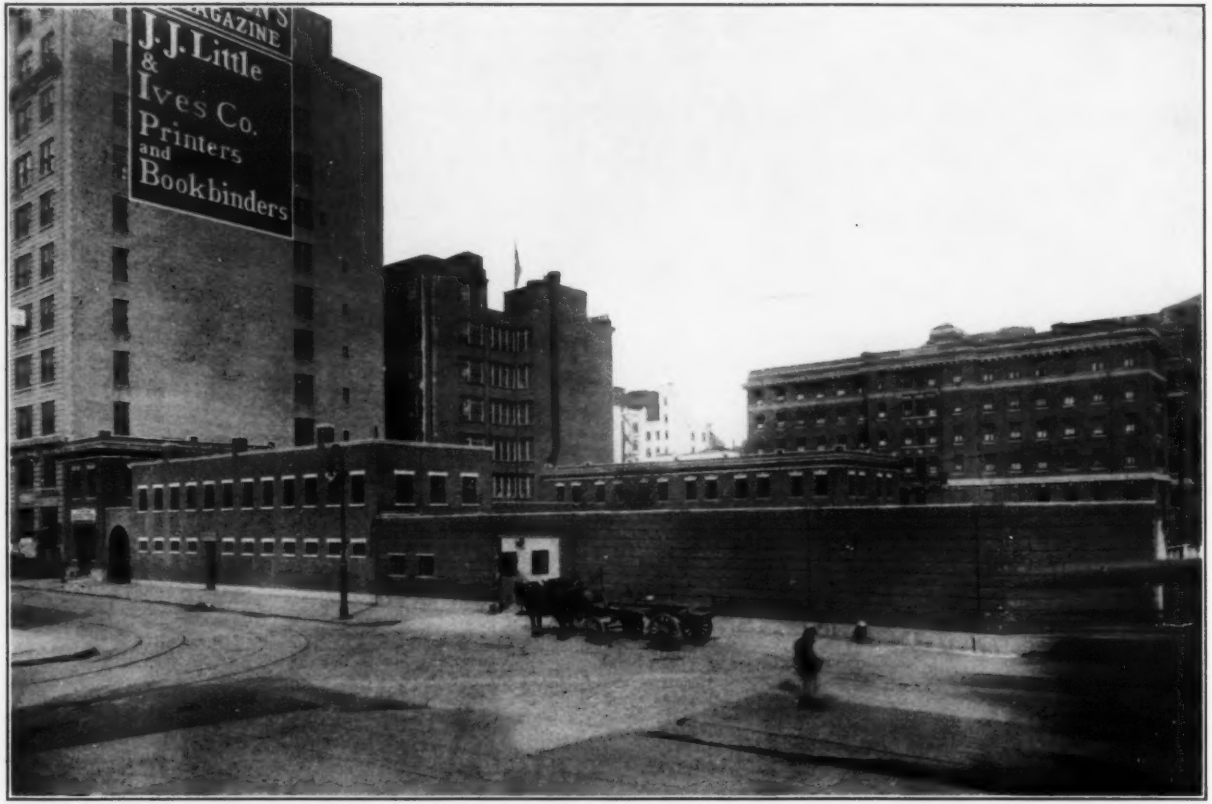


PLATE 4. EAST 24TH STREET YARD, BOROUGH OF MANHATTAN. HEADQUARTERS FOR REPAIR COMPANY, METER SHOP, STOREROOM AND GARAGE

TABLE 4

Standard quota of equipment for repair companies.
Manhattan and the Bronx
February 8, 1915

For office use:	
Mops, complete	2
Mop wringer	1
Whisk brooms	2
Duster	1
Corn brooms	2
Fire extinguishers	2
Ash cans	2
For shop use:	
Buck saw	1
Saw horse	1
Garden hose, feet	50
Step ladder	1
Platform scale	1
Anvil	1
Kerosene cabinet	1
Iron rake	1
Work bench	1
Vice (combination)	1
Breast drill	1
Stock and dies (for pipe thread)	3
Stock and dies (for machine thread)	3
Ratchet brace and set of bits	1
Draw knife	1
Spirit level	1
Grindstone	1
For general use:	
Rubber boots (for each man)	
Rubber hats (for each man)	
Oil suits for all, except foremen	
Rubber coat for each foreman	
Axes, 3-pound	3
Axes, 5-pound	3
Hatchets	3
Aquaphones	2
Crow bars, 6-foot	3
Telegraph bars, 6-foot	3
Pinch bars, 4-foot	2
Cutters (bull point)	12
Brushes (casting)	3
Cutters (asphalt)	12
Hook chains, ½-inch x 12 feet	2
Hook chains, ¾-inch x 12 feet	2
Cutters, pipe	2

TABLE 4—Continued

For general use—Continued:

Derrick, 1-ton	1
Derrick, 2-ton	1
Rope chain slings	2
Rope slings for 12–20 and 36-inch pipe, 2 of each	2
Files, 8–10 and 14-inch, 3 each of the following, bastards, half round, hand and square, second cut (flat)	3
Files, saw (8-inch)	3
Hydrant pressure gauges and connections	6
Striking hammers	6
Malls	2
Mortar hoes	2
Water hose, 2½-inch, feet	50
Hydrant pumps	2
Furnace (plumber's)	1
Furnace, 18-inch caulker's	1
Gate keys (different lengths)	12
"Wells" lights	2
Lanterns, dozen	5
Search lights (electric)	2
Ladles, 9-inch	2
Ladles, 7-inch	2
Pouring pots and hooks	2
Melting ladles and tripods	2
Ditch pumps (G. I.)	2
Dia. pumps, No. 2 (complete)	2
Dia. pumps, No. 3	2
Dia. pump, gas driven	1
Picks, dozen	1
Pails (G. I.)	6
Rammers	6
Asbestos joint runner, 48-inch	1
Asbestos joint runner, 30-inch	1
Asbestos joint runners, 20-inch	2
Asbestos joint runners, 12-inch	2
Asbestos joint runners, 8-inch	4
Asbestos joint runners, 6-inch	4
Shovels (D. handle R. P.)	15
Shovels (L. handle R. P.)	4
Shovels (D. handle sq. p.)	6
Shovels (L. handle sq. p.)	6
Telegraph spoons	2
Screw drivers, 24-inch	4
Screw drivers, 6-inch	2
Sledges, 24-pound	3
Sledges, 20-pound	3
Wheel tool box	1

TABLE 4—Continued

For general use—Continued:	
Trowels	3
Tape, 50-foot	2
Rule, folding	6
Pipe vise (portable)	2
Street brooms	6
Wrenches (monkey, 6- to 18-inch)	9
Wrenches (Stillson 8- to 26-inch)	9
Wrenches, hydrant	12
Wrenches, special for various makes of hydrants	
Saw, two-man	2
Saw, cross-cut	2
Saw, hack	3
Pliers, 4-inch, pairs	3
Pliers, 12-inch, pairs	3
Tin snips, pair	1
Soldering iron (1-pound)	1
Extra length of 2½- and 3-inch suction hose with strainer, each	1
Caulking tools and implements (for each caulker employed)	
Hammer	1
Yarning irons	2
Chisels (small bursting)	2
Chisels (lifting)	2
Chisels (cold)	2
Chisel (dog)	1
Chisel (dog diamond point)	1
Chisels (hand diamond point)	2
Wedges, large bursting	2
Hammer (3½-pound)	1
Tool bag	1

The sizes of pipe used are 6-inch, 8-inch, 12-inch, 16-inch, 20-inch, 24-inch, 30-inch, 36-inch, 48-inch, 60-inch, 66-inch. For sizes above 48 inches steel is generally used; while for 48 inches and smaller sizes, cast iron is adopted. The pipe and specials are made from department designs, although the writer believes that a change to American Water Works Association standards for the pipe at least, will be made before long.

Valves are made from department design under definite specifications. The sizes adopted are 6-inch, 8-inch, 12-inch, 20-inch, 36-inch and 48-inch. Intermediate sized mains have valves with reducers. Thus, 36-inch valves are used on 48-inch and 36-inch mains, 20-inch valves on 30-inch, 24-inch and 20-inch mains, 12-inch valves on 16-inch and 12-inch mains. This practice requires

fewer valves in stock, greater ease and speed in operation of valves and less parts for repairs. The additional loss in head, due to contraction of waterway is negligible. Thus, with a velocity in the main of three feet per second, the loss at the valve, due to placing a 20-inch valve on a 30-inch main, is about a half an inch, while the frictional loss per 1000 feet would be about a foot. As valves are only placed at intervals of about 2000 feet on the larger mains the effect is not practically measurable.

The use of department designed valves has not materially increased the cost, as the prices quoted for valves delivered during the past year have been approximately as follows: these valves being a heavy bronze stem bronze mounted type:

Size In.	*Av. Cost*	*Size In.*	*Av. cost*
4	$8.00	12	$31.00
6	12.00	16	65.00
8	18.50	20	115.00

The hydrants used are also manufactured from department drawings and specifications. The body is 8 inches in diameter, with one 2½-inch and one 4½-inch outlet. These hydrants manufactured of high grade materials, and under careful inspection are now delivered at less than $25 per hydrant.

To receive all equipment, materials and supplies, and care for same before use, three general store yards have been established, one in Manhattan to serve Manhattan, The Bronx and Queens, and one each in Brooklyn and Richmond to serve those boroughs. For pipe, special castings and other heavy materials additional yards have been established in each borough.

Machine Shops

Repairs to valves, hydrants and other appurtenances require machine work which is carried out in a well equipped shop in Brooklyn, where eight machinists and an equal number of helpers are employed. In Manhattan, less work of this character is performed by the city force, and only two machinists and helpers are assigned to distribution work. The Brooklyn shop is headquarters for the automobile repairs and as the department has over thirty cars with approximately as many more to be purchased in 1915, this part of the work is important.

Meter Shops

Under the New York City charter, meters are furnished and set by property owners upon the direction of the department. Under present regulations the department cannot require meters to be set except where water is used for business purposes. The meter rate is 10 cents per 100 cubic feet, irrespective of quantity used. This rate is approximately double the average income per million gallons delivered into the mains. It is therefore to be expected, as the frontage rate is in general materially less than meter rates, that meters will not be set except upon the order of the department. There are approximately 90,000 meters in use in the city. The charter further requires that all meters shall be of a type and sold at a price approved by the Board of Aldermen, upon recommendation of the commissioner of the department. There are seventeen makes of meters approved, thus affording the consumer a wide range in choosing his meter.

Before meters are set they must be tested for accuracy at one of the department shops, no charge being made for such test. After being set they are subject to retest at such times as may be directed by the department. The department does not make any repairs to meters, but requires the plumber to remove the meter, attend to the repairs and deliver the meter to the meter shop for test and certification. These meter shops are equipped with modern appliances, the installation at the 24th Street shop, Manhattan, where the majority of meters are tested, being shown by photograph, Plate No. 5. Large meters, above 2 inches in diameter, are frequently tested on the premises without moving same, by the installation of a test tee on the delivery line just beyond the meter and the use of a portable test meter which is attached by the inspector to the test-tee outlet. Where a large meter is found to be registering incorrectly the same may be repaired either in place or removed for repairs, at the option of the owner. The number of meters tested annually by each shop is as follows:

Manhattan	Premises	2547
	Shop	18196*
Bronx	Premises	738
	Shop	2177

* Includes meters sent from Queens and Richmond.

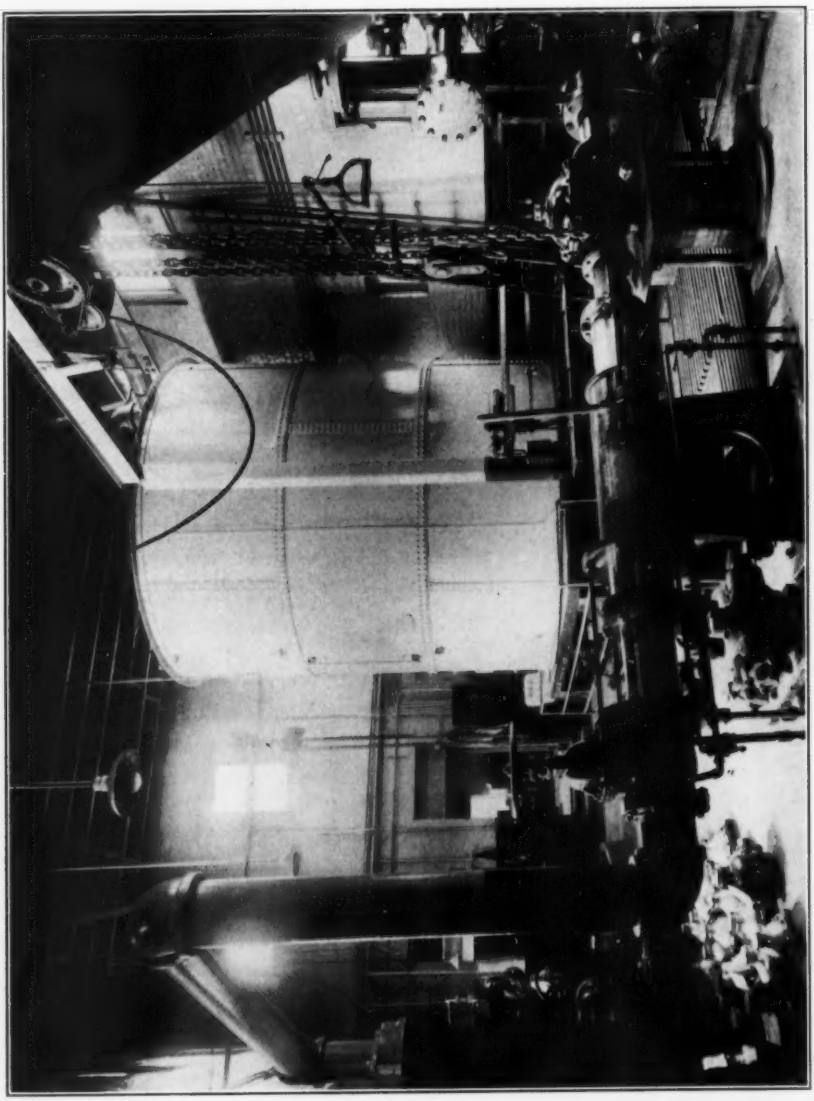


PLATE 5. EAST 24TH STREET YARD, BOROUGH OF MANHATTAN. INTERIOR OF METER TESTING SHOP

Brooklyn	Premises	2039
	Shop	6803
Queens	Premises	38
	Shop	—
Richmond	Premises	35
	Shop	—

The force employed in the Manhattan shop, where the largest amount of work is done, is as follows:

1 Inspector	$1500
2 Inspectors	1100
1 Clerk	900
1 Stenographer	1050
1 Plumber	5.50 a day
1 Machinist's Helper	3.00 a day
5 Laborers	2.50 a day

TRANSPORTATION

Until approximately 1913, all transportation was by horse-drawn vehicles, city owned horses and vehicles being used in the boroughs of Brooklyn and Richmond and hired horses and vehicles in the other three boroughs. This difference resulted from continuation of practices followed before consolidation in 1898, there being no local transportation conditions which warranted a different system in one borough as compared with another.

The development of the automobile has resulted in a change in policy and light auto runabouts, with small wagon bodies, are used for the foremen, tappers and for light material, while auto trucks are being substituted for the horse-drawn trucks. The horse-drawn and motor-driven types are illustrated in photograph, Plate 6. It is estimated that the cost of transportation by horse-drawn and by motor-driven vehicles is approximately the same, based on mileage. The load transported, however, is mainly labor, and therefore the saving in time should be multiplied by the number of men transported, which is usually six to each gang. The main advantage in the use of motor vehicles is in the reduction in time in responding to emergency calls, and the resultant reduction in damage caused by breaks in large mains, and the much more efficient supervision by the foremen, where automobiles are available.

The department records on automobile service show the following

PLATE 6. AUTOMOBILE RUNABOUT USED FOR FOREMEN, TAPPERS AND LIGHT REPAIR WORK. HORSE DRAWN WAGON. THESE WAGONS BEING REPLACED BY MOTOR TRUCKS

cost per mile for runabouts, touring cars and trucks, exclusive of the cost of driving:

Runabouts	4.6 cents per mile
Touring cars	7.7 cents per mile
Trucks	6.3 cents per mile

The touring cars are used by the superintendent and assistant engineers in charge of maintenance work.

The department has one three-horse truck, which has sufficient carrying capacity to handle any pipe or valve that might be required for repair or extension work, and it is proposed to continue this truck in use for emergencies even though automobiles may be substituted for all other transportation.

METHOD OF REPORTING REPAIRS REQUIRED

When a complaint is received at a repair company's headquarters, entry is made in a blotter kept for the purpose and the complaint is transmitted by telephone to the borough office. Here a complaint slip is made out in triplicate, two copies being forwarded to the repair company's headquarters, the third being retained as an office record. If a complaint is received directly at the borough office, a similar complaint slip is made out and forwarded to the repair company. The form of slip used is reproduced on plate No. 7. Each complaint is given a job number and all time and material consumed is charged to that job. When the complaint has been attended to, the clerk at the yard notes the action taken on the complaint slip and the duplicate is returned to the borough office. The record of material and time charged to the job is sent to the division of costs and statistics, which records all departmental expenditures.

Immediate action on complaints of an urgent character is taken by the foreman in charge of the repair company, the regular complaint slip being later forwarded to headquarters.

In the borough office there is a street map, mounted on soft wood, and pins with varicolored heads are daily placed at the locations of the different complaints. The assignments of gangs to jobs for the following day are also shown on this map; so that it can be determined at a glance the number and kind of complaints that have not yet been attended to, as well as the location of each gang.

Distribution Division Form No. 1b ORDER ON REPAIR COMPANY 38 D-1-14 (B) 7500

CITY OF NEW YORK

DEPARTMENT OF WATER SUPPLY, GAS AND ELECTRICITY

BUREAU OF WATER SUPPLY

ORDER No..... COMPANY No.....

Com. No.	Ch. Eng. No.	Page No.

Received 191 , M., from

Sent on 191 , M., to Foreman of Repair Company

Assigned on 191 , M., to

Location

Complaint

REPORT

.....

Foreman.

PLATE 7—COMPLAINT SLIP

For the high pressure fire system, the procedure provides for notification of the fire department of all changes which affect that part of the system. If, for any cause, a hydrant cannot be utilized, a chain is attached thereto, carrying a metal tag on which are inscribed the words "Out of Order."

In general, the repair work is kept up so that routine repairs are made within two or three days from the receipt of complaint and emergency repairs are, of course, attended to immediately.

Taps

The department furnishes and places all taps and connections to city mains, the taps including wet connection sleeves and valves up to 20 inches by 24 inches being manufactured under departmental designs and specifications. Application for the tap is presented by a licensed plumber, and the size of tap granted is based upon the number of square feet of floor area in the building, the general standard being shown in the following schedule:

The area of one $\frac{5}{8}$-inch tap shall be credited for the first 7500 square feet of floor area, one $\frac{3}{4}$-inch for the first 15,000 square feet and above 15,000 square feet one $\frac{5}{8}$-inch tap for every 10,000 square feet of floor space thus computed (or an equivalent combination of larger taps) viz:

Up to 7,500 square feet	1-$\frac{5}{8}$-inch tap
7,500 to 15,000 square feet	1-$\frac{3}{4}$-inch tap
15,000 to 20,000 square feet	2-$\frac{5}{8}$-inch taps
20,000 to 30,000 square feet	3-$\frac{5}{8}$-inch taps (or 2-$\frac{3}{4}$-inch taps)
30,000 to 40,000 square feet	4-$\frac{5}{8}$-inch taps (or 3-$\frac{3}{4}$-inch taps)
40,000 to 50,000 square feet, etc	5-$\frac{5}{8}$-inch taps (or 2-1 inch taps)

Where the occupancy of a building will require an unusual volume of water, the size of tap granted is in accordance with the probable demand. This system of floor area as a basis for determining the size of tap has been in use for the past three years and has given general satisfaction. Prior to its adoption, there was no standard by which to judge the size of tap to be allowed and there was, naturally, resultant dissatisfaction and charges of favoritism. After the size of tap has been determined, the excavation is made by the plumber, who notifies the department that the opening will be ready for the tapper on a given date and hour. The tapper is furnished with a

card authorizing him to insert a given sized tap and he returns this card with endorsement showing the size of tap inserted and the location of same. This information is then transferred to a tap card for filing, illustrated on Plate No. 8.

The department charges the property owner a fixed price for each size of tap, the present schedule being as follows:

CHARGES FOR WET CONNECTIONS

Connection	*Pipe Inches*	*Rate*
2 inch	6	$23.95
	8	25.45
	12	34.70
	16	40.45
	20	48.20
4 inch	6	27.50
	8	30.20
	12	38.15
	16	43.90
	20	51.65
6 inch	8	36.55
	12	45.95
	16	54.70
	20	59.95
8 inch	12	55.00
	16	66.75
	20	71.25

CHARGES FOR TAPS

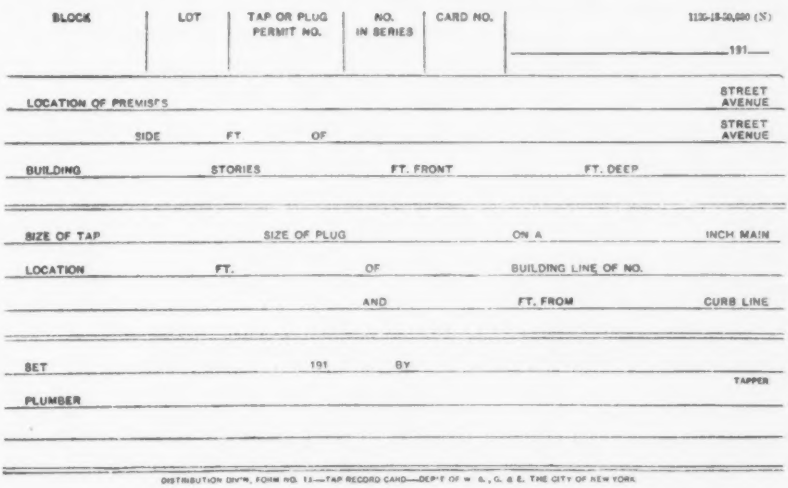
Size	*Rate*
$\frac{5}{8}$-inch	$4.50
$\frac{3}{4}$-inch	5.00
1-inch	6.00
2-inch	15.00

All house services up to and including two inches in diameter are required to be of lead from the tap to the property line. The tap and service is inspected by an employee of the Bureau of Water Register, and the charge for water dates from the approval of the service and the turning on of the corporation cock. This cock is buried in the street and a curb cock set at the curb line.

Shutting Off Leaky Service

When notice of a leak is received effort is made by examination of the surface and use of the aquaphone to determine whether the

leak is on a service or the city main. As the services are owned by the property holder, he is notified to make repairs, if the leak is probably on his service. If its location is uncertain, the department gang digs up the main and continues excavation until the leak is found. If the leak is finally found on the city main it is repaired by the city force. If the leak is on a private service, the corporation cock is shut off and the repair work is turned over to the plumber representing the property owner. The department formerly billed the property owner for all excavations necessary to locate the leak. This procedure resulted at times in a severe


BLOCK | LOT | TAP OR PLUG PERMIT NO. | NO. IN SERIES | CARD NO. | 1135-15-50,000 (S) 191

LOCATION OF PREMISES ____ STREET AVENUE

SIDE ____ FT. ____ OF ____ STREET AVENUE

BUILDING ____ STORIES ____ FT. FRONT ____ FT. DEEP ____

SIZE OF TAP ____ SIZE OF PLUG ____ ON A ____ INCH MAIN

LOCATION ____ FT. ____ OF ____ BUILDING LINE OF NO. ____

AND ____ FT. FROM ____ CURB LINE

SET ____ 191 ____ BY ____ TAPPER

PLUMBER ____

DISTRIBUTION DIV'N, FORM NO. 13—TAP RECORD CARD—DEP'T OF W. S., G. & E. THE CITY OF NEW YORK

PLATE 8. RECORD TAP CARD

burden being placed upon the property owner, as where the subsurface conditions were favorable, such as in a rock filled street, the leaking water might run for several hundred feet before it appeared at the surface. Numerous openings had to be made before the leak was discovered, and bills of several hundred dollars were not uncommon. Now the department charges only for the excavation which finally locates the leak, believing that the city should carry the extra charge as an insurance against any one property owner being heavily penalized, due to no fault of his own.

While curb cocks are installed, they are not of material use in locating leaks on services, as such leaks are usually between the main and the curb cock.

To insure payment for work done by the department, the plumber is called on to assume responsibility for the pavement disturbed and excavation made before the water is again turned on.

Pressure in Premises

New York City has, in general, a low pressure, the average in Manhattan and The Bronx being about 30 pounds, Brooklyn and Queens have approximately 35 to 40 pounds, while Richmond varies from over 100 pounds down to 20 pounds or less.

Many Manhattan and Bronx premises have tanks or house pumps, or both, but even with such auxiliaries in use the complaints of lack of pressure are quite frequent. Such complaints are turned over to an inspector who takes the pressure at the nearest hydrant, in the basement and on each floor, with and without a faucet flowing, and notes the size of the supply pipe from the main and the size of each riser and number of floors supplied by each. After the data obtained has been studied, the owner is notified of the conditions found, the probable cause of lack of pressure, and what action is necessary to remedy the conditions complained of.

Hydrant Repairs During Freezing Weather

The fire department force make continual inspections of hydrants during the winter months and report to the repair company headquarters hydrants that are frozen or in danger of freezing. These are then examined by the department force and the waste drip cleared and hydrant drained or else pumped out. Salt is placed in hydrants which leak slightly and do not drain properly. Experiments with the use of glycerine, alcohol, and carbide of lime as substitutes for salt are being made, but there is not sufficient data available on which to draw conclusions. Hydrants that are frozen are thawed out by the fire department, using the standard steamer, and by the water department, using a special portable boiler.

Operation of Valves

With about 60,000 valves in the system, it is difficult to operate the valves frequently enough to keep all valves in good condition. The department plans to operate and oil every valve once a year,

but so far has been able to keep up to this schedule for the large valves only, i.e., larger than 20 inches in diameter. With New York City water if valves are operated once each year they are kept in good general condition ready for operation at any time. It has recently been the practice to place metal pans over the gears to protect them from dirt. The boundaries of services are usually formed by closing valves, thus creating dead ends. Sediment collects in such dead ends and can only be removed by partially opening the valve and blowing off the sediment laden water through the adjoining hydrants. Special gangs are operating continuously on this work, the mains being blown out at intervals of from two weeks to several months, the time depending upon the rapidity with which sediment forms in objectionable quantities.

Response to Fire Alarms

The water department is responsible for the adequacy of the supply for fire extinguishment. Fire alarm gongs are located in all repair company headquarters, and a repair company gang responds to all two alarm fires in the low or domestic pressure districts. To all alarms in the high pressure fire service district, a special repair gang responds. On arriving at the fire the driver gets in touch with his headquarters so the gang can be located, and the men are held to act in case of emergency, such as lack of water, which might be relieved by opening adjacent district boundary gates. The foreman notes the location and number of engines, water pressure, etc.

Assignment of Assistant Engineer for Night and Holiday Duty

On the theory that men familiar with the water supply system and competent to act in emergencies should always be available, assignments are made so that two engineers, one for Manhattan and The Bronx, and one for Brooklyn, are always in reach of the telephone from the time the office closes until it is again opened. The city furnishes telephones in the homes of these men, but they do not receive any added compensation due to such additional duty. These men are called out for three or four alarm fires, as well as in emergencies resulting from any cause. They take charge until they are relieved by a higher official.

Controlling Pressures in Mains

Recording pressure gauges are located in the various repair headquarters and pumping stations, and also in some sixty fire company engine houses scattered throughout the city. These gauge charts show if there has been any unusual pressure changes and studies can then be made to determine cause and remedy.

The pressure in the Brooklyn low pressure system and the First Ward, Queens, is controlled by the operation, day and night, of headgates at the reservoir. If the pressure is normally in the day time between 35 and 40 pounds, it will rise above 45 pounds at night when such increase in pressure is useless. The pressure is, therefore, kept high from 5 a.m. to 11 a.m. From then until midnight it is kept about 5 pounds lower than during the morning, and at midnight it is further lowered about 6 pounds and kept at the low point until five in the morning, when the gates are again opened. With four 48-inch and two 36-inch mains feeding the service from the reservoir through six 36-inch valves, it is found necessary to have all valves opened from 12 inches to 18 inches in the morning, there being no effect if the valves are opened more than 18 inches. During the early morning hours three of these valves will be shut, two opened about 4 inches, and one, on a main that feeds a service pumping station, about 12 inches. Pressures are telephoned to the reservoir every hour and more frequently, if required, and men are on hand to immediately open valves if required. If a three alarm fire is recorded the valves are immediately opened, about ten minutes being required to give full pressure.

This system has been in use for nearly ten years, and no trouble has been experienced. The control of the pressures reduces the consumption by over five million gallons daily, or about five per cent of the total supply to this service. When all the water is pumped and difficult to obtain, this saving in water is material and is worth financially between $100 and $200 per day.

Measurements of Flow in Mains and from Hydrants

In studying trunk main capacity, the distribution of the flow is an important factor in determining whether existing mains are being utilized to full capacity, and also whether new mains are needed. Pitometer surveys are being made from time to time for this pur-

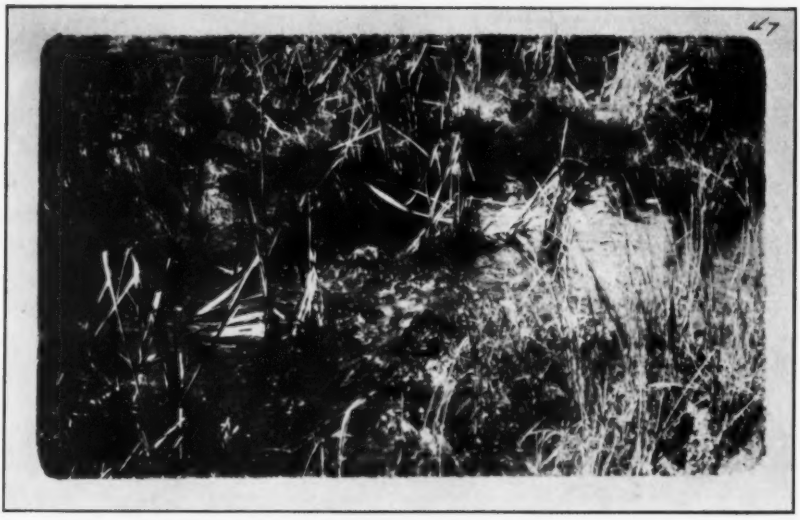
pose, three parties being continuously employed on this and similar work, the department owning 15 instruments. Measurements of flow are also undertaken to determine leaks outside of premises and as a result of such work during the past four years, i.e., from 1910 to date, leaks in mains and services have been located and stopped, amounting to 33 m.g.d. An interesting leak that was found by such measurements is shown on Plate No. 9. This was considered by the local inhabitants to be a spring which yielded water of a superior quality to the city water, and they were much surprised when the leak was discovered and the spring ceased to flow. The volume of water lost through fixture leakage is determined by the pitometer measurements, flows being recorded into districts before and after water waste prevention inspections have been made. The adequacy of the distribution system to deliver an ample supply for fire extinguishment is determined by testing the flow from hydrants, usually using a group of six and noting the drop in pressure and the discharge from each hydrant. Pitot nozzle gauges are used for this purpose, the force employed being the regular pitometer survey force.

Checking Waste in Building

Waste of water from fixtures within buildings has always been one of the problems that water works engineers and superintendents have had to contend with, and no satisfactory answer except metering has been found. Where metering is not permitted some other means must be adopted if the consumption per capita is to be kept within what is generally considered reasonable limits.

The consumption in Manhattan and The Bronx in 1910 was 331 m.g.d. with an estimated population of 2,762,500, making the per capita consumption 120 gallons daily. For the twelve months from July 1, 1911, to July 1, 1912, the consumption was 291 m.g.d., which, with an estimated population of 2,838,500 in 1911 would give a per capita consumption of 103 gallons daily. For Brooklyn, with a consumption of 155 m.g.d. and a population of 1,685,000 there was a per capita consumption of 92 for 1911, which was 5 gallons less than that recorded for the preceding year. In 1913 the consumption was 140 m.g.d. with a population of 1,791,100, giving a resultant per capita consumption of 78 gallons daily.

The reduction in consumption has been accomplished by water waste prevention inspection and by the stoppage of leaks in the



LEAK AMOUNTING TO 1,400,000 GALLONS PER DAY, WHICH APPEARED AS A "SPRING" IN A SWAMP 100 FEET FROM THE LEAK. LEAK DISCOVERED BY PITOMETER MEASUREMENT

LEAK FROM MAIN RISING DIRECTLY OVER BREAK WHEN OPENING WAS CUT THROUGH SWAMP SOD. SHUTTING OFF OF THIS LEAK IN THE 8-INCH MAIN INCREASED THE PRESSURE ON A PARALLEL 20-INCH MAIN FROM 36 POUNDS TO 51 POUNDS

distribution mains and service pipes outside of buildings. It has already been stated that the total amount of leakage outside of buildings discovered and stopped during the past five years has amounted to about 33 m.g.d. The main reduction in consumption has therefore resulted from the water waste prevention work. The general procedure followed in this work is as follows:

Printed notices are delivered on the premises, calling attention to the necessity of preventing waste of water. This is followed by a house to house canvass, all fixtures being examined by an inspector. If any leaks are found the inspector leaves a notice of such leaks, the notice calling for repairs to be made within three days. A duplicate of this notice is mailed to the premises from the department office. A re-inspection is made after three or more days and if all leaks have not been repaired a fine of $2 per premise is imposed. This fine is repeated if later inspection shows that the necessary repairs have not been attended to.

Before the inspectors go into any district, pitometer measurements are taken on mains which can feed said district, valves being temporarily closed to fix the boundaries. After the inspection is completed and the leaks stopped, the flow into the district is again measured and the leakage stopped computed.

Two extensive inspections have been made during the past four years, one in 1911 in Manhattan where the maximum leakage stopped in a five months' campaign was estimated to be 71 m.g.d., of which 21 m.g.d. is attributed to the house to house inspection and the other in 1912–1913 in Brooklyn, where it was estimated 30 m.g.d. was saved as a maximum. The inspectors employed in the first investigation reached a maximum of 114, while the total number of inspector days expended in inspecting and re-inspecting buildings and locating 197,000 leaks was 11,600 days. Each inspector received at the rate of $1100 per annum and pitometer gaugings of flow into districts inspected cost about 35 percent of the inspection cost. The fines imposed just offset, however, the cost of these gaugings. The net cost of saving the water, assuming that all the leakage stopped would eventually reappear in two years time (experience shows that the actual time is longer) was about $7.70 per m.g.

In Brooklyn in ten months, with nearly forty inspectors and 8800 inspector days, the net cost of saving the water was estimated at $3 per m.g. using the same basis of computation as for Manhattan.

The maximum daily reduction in consumption per inspector employed is estimated at 900,000 gallons. The yearly reduction in annual expenditures resulting directly from this checking of leakage is estimated at $400,000, while the total cost was about $36,000, and the net cost, allowing for fines imposed, less than $30,000.

The limited data available indicates that after six months' work the inspector is stopping leakage at about the same rate as the leakage previously stopped is reappearing. The work of inspection is under the Bureau of Water Register, but the outlining of the water waste prevention campaigns has been done by the Bureau of Water Supply.

RECORD MAPS OF DISTRIBUTION SYSTEM

For general use as wall maps and for the use of foremen and others in the field, tracings to a scale of 400 feet to the inch have been prepared, showing by symbol size of mains, connections, valves, hydrants, blowoffs, etc. Street lines are omitted except in outlying sections, as the mains indicate the streets and the additional lines are confusing. These maps are kept up to date and prints in the repair companies' headquarters are corrected each month as far as practicable. The boundaries of services are shown by colors.

Atlases to scales of 100 feet to an inch and 160 feet to an inch have been tried to record actual locations of mains, valves, hydrants and appurtenances, with depth of cover, when laid, etc. These have not been a success and it is considered that drawings to a scale of 40 feet to an inch will be more suitable with a scale of 20 feet to an inch being used where there are very complicated intersections. On the large sized scales can be shown location of taps as well as other details.

For the high pressure fire system each hydrant is numbered and maps to a scale of 300 feet to an inch are used for general maps, with the same sized scales for the detailed maps.

All the work of collecting, transporting, pumping and distributing the water supply for Greater New York is under Mr. Merritt H. Smith, Chief Engineer of the Bureau of Water Supply. The writer as Deputy Chief Engineer has come in close touch with the maintenance and operating problems and has found these studies most interesting. A more general statement of practice by the various water departments of our cities would be helpful in developing sound procedure in this branch of water supply.

DISCUSSION

MR. D. W. FRENCH: Will Mr. Brush kindly state whether should a break occur in the pipe system during a period of fire, resulting in a general reduction of pressure in the high pressure system, the department have any means of controlling the gates to shut off the damaged part of the pipe system, electrically from some central station, or if the gates would have to be operated by hand.

MR. WILLIAM W. BRUSH: In the domestic system, New York City does not have any hydraulically or electrically operated valves which may be opened from a distant control point to permit delivery of the supply from a higher level district into a lower level district. The boundaries of the different services are created by closing valves, and in case of an unusual demand, created by a break or other cause, one or more of these boundary valves are opened by the repair gang. In general, the distribution system is so proportioned that there is little need of delivering water from a higher to a lower level, although ten years or more ago this was necessary rather frequently in cases of large fires located near boundaries of services.

In the High Pressure Fire Service system there are electrically operated valves controlled from the pumping stations and used to separate the system into two parts, said valves being closed in case of a break. In the newer parts of the system alternate streets are on one system with intermediate streets on the other system, thus materially reducing the danger of the whole system becoming inoperative throughout any district, due to break in the mains or appurtenances.

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Mueller Manufacturing Company, H. 10
Smith Manufacturing Company, The A. P. 1

NICHOLAS S. HILL, JR.
PRESIDENT 1915-1916